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# Exploring the human computer interface and photic driving

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# NAVAL POSTGRADUATE SCHOOL
## Monterey, California

# THESIS

**EXPLORING THE HUMAN COMPUTER INTERFACE AND PHOTIC DRIVING**

by

Robert B. Peterman

March 1999

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In the software design, two Java applets were written which caused the flashing of the screen in both a regular, set frequency and at a random frequency. A webpage was developed as a container for a subset of the Kit of Factor-Referenced Cognitive Tests. An empirical study was performed utilizing a light/sound machine, the Java applets as well as the cognitive tests. Twenty-five subjects were divided into three sample groups and their performance during all phases of the study were recorded and analyzed. Analyses of the results indicate that no direct correlation between photic driving and test score can be proved. Subjects' comments following their participation indicate however that there were some significant effects caused by the photic driving that were not reflected in the test scores.

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# EXPLORING THE HUMAN COMPUTER INTERFACE AND PHOTIC DRIVING

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Submitted in partial fulfillment of the
requirements for the degree of

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## ABSTRACT

The application of a stroboscopic light within a certain frequency range may cause a subject's brain waves to follow or become entrained to the same frequency as the flashing light. This phenomenon is known as photic driving. The objective of this study is to determine if computer monitors can be used as the presentation medium for photic driving, and to investigate whether any measurable cognitive changes can be caused through this photic driving.

In the software design, two Java applets were written which caused the flashing of the screen in both a regular, set frequency and at a random frequency. A webpage was developed as a container for a subset of the Kit of Factor-Referenced Cognitive Tests. An empirical study was performed utilizing a light/sound machine, the Java applets as well as the cognitive tests. Twenty-five subjects were divided into three sample groups and their performance during all phases of the study were recorded and analyzed. Analyses of the results indicate that no direct correlation between photic driving and test score can be proved. Subjects' comments following their participation indicate however that there were some significant effects caused by the photic driving that were not reflected in the test scores.

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# I. INTRODUCTION

## A. MOTIVATION

In the latter part of the 1960's and early 1970's, the Bioengineering Project at the Naval Postgraduate School (NPS) was analyzing the frequencies of the electroencephalogram (EEG). This research focused primarily on the application of pattern recognition to detect changes EEG in response to specific stimuli [PARS76]. Since 1976, little to no research involving EEGs was pursued at NPS.

## B. OBJECTIVE

It has been known to military organizations since at least the early 1960s that computers generate electromagnetic radiation that not only interferes with radio reception, but also leaks information about the data being processed [KUHN98]. This undesirable electromagnetic emanation is controlled via expensive protective shielding of electrical equipment so that equally expensive monitoring of the emanations, collectively known as TEMPEST, is not possible. In 1985 Wim van Eck published a paper in which he discovered that eavesdropping on a video display unit is possible at several hundreds of meters in range using inexpensive and readily available items such as a black-and-white TV receiver, a directional antenna and an antenna amplifier [ECK85]. What once required sophisticated detection and decoding equipment was now accessible to the masses, terrorists included.

Ever since Berger (1929) demonstrated that it is possible to record the electrical activity of the brain by placing electrodes on the surface of the scalp, there has been considerable interest in the relationship between these recordings and psychological processes [COLE90]. If the brain emanations, or signal, can be detected much like

TEMPEST radiation, can we also decode it as we do TEMPEST radiation? Keirn and Aunon described a procedure in which it is possible to distinguish various mental tasks, using only the EEG, to a high degree of accuracy [KEIR90]. Although this is a promising beginning, neurophysiology, computer science and biomedical engineering have not yet advanced to the point where scientists can actually "read minds".

It is the intent of this thesis to become the foundation for a new area of research at the Naval Postgraduate School in the Human Computer Interface (HCI). Specifically this research will deal with the potential for exploiting the human computer interface by altering EEGs via photic driving (PD). By using PD, the author will attempt to alter the brain's functions and elicit a general change in cognitive functioning. To measure the effect of changing the overall EEG of the brain through PD, the experimental procedure measured the changes in performance and alertness. This requires a knowledge base including a thorough study of neocortical cells, EEG physiology, unfiltered wide band EEG spectral analysis, and computerized EEG analysis.

## C. APPROACH

This thesis is unique in that the intent of the research alters the subject's EEG without the subject's knowledge through the use of PD, and explores the possible presentation of the computer code through remote computer network insertion. Other research is based on active and knowing participation by the subject and biofeedback techniques.

The most obvious method of interfacing with a subject at a computer without their knowledge is to attempt to influence them through the CPU or video monitor emanations. Due to previous research results in photo-stimulation, the author chose to attempt modification of the subjects' EEG through the CRT emanations.

## D. THESIS QUESTIONS

This thesis will attempt to answer the following questions:

- **Can photo-stimulation be used to alter a subject's cognitive functioning?**

  Researchers have shown that changes can be detected in an EEG pattern when a subject is exposed to photic driving stimuli [GIZY93, MANG93], and SAKA93]. By changing the EEG of a subject, other researchers have shown that a subject's mood can be affected [GIZY97]. Other researchers have shown that the brain can heal itself from alcoholism, learning disorders and increase an IQ [HUTC94]. By changing the cognitive functioning or mood of a subject, their ability to remain alert and increase their productivity may be affected.

- **By what procedure can this be shown empirically?**

  It is only through direct observation of the subject while they are being exposed to photo-stimulation can we determine if driving of the brain waves or that alteration of the cognitive functioning has actually occurred. The need to observe the subjects, record feedback from the subjects and evaluate subject performance during the exposure to photo-stimulation to insure that any alteration is detected reinforces the need for an empirical study. Not only will an empirical study provide data from which conclusions can be made, but it could also provide data that generates further questions and areas of follow on research.

- **Can the photo-stimulation be "hidden" from the subject?**

  The use of placebos in medical experiments is commonplace. If a patient believes that they are being treated with a drug, even if they are only getting a sugar tablet, they may show improvement in their condition. By hiding the existence of photic driving stimuli, any placebo–like effects can be avoided.

- **What cost-effective mechanisms can provide hidden photo-stimulation?**

  A cost-effective mechanism would contribute to the potential use of this form of photo-stimulation. Dissemination of the photo-stimulation process would be significantly enhanced if the cost to the provider and the user were small.

  - **Is it possible to produce a desired change in cognitive functioning in the subject?**

    As noted earlier, it has been shown that a subject's mood can be affected by exposure to photo-stimulation. The ability to target a specific cognitive function for change would allow a subject to be exposed to photo-stimulation in different situations with different desired results. If a desired change could be produce, situation dependant application of photo-stimulation could be used to stimulate alertness in one environment, promote relaxation in another environment, and even increase creativity in another environment.

- **By what methods can the desired changes be observed?**

  A method that accurately evaluates and reflects changes in cognitive functioning is desired. The method must be incorporated into the overall empirical design in order to eliminate variables and to limit the scope of observations required. Without a properly evaluated and observable change in the cognitive functioning of a subject, no definitive conclusions can be drawn regarding the effects of photo-stimulation.

## E. THESIS OUTLINE

Chapter II of this thesis provides a brief overview of the human nerve cell, its electrical activity, and the electroencephalogram. Also included in this chapter is a review of current research in the area of the HCI and neurophysiology. Chapter II concludes with a presentation of photic driving as the primary tool for this research. Chapter III describes the methodology used in the empirical study and discusses the limitations of the experimental protocol. Chapter IV provides a detailed analysis of the results from the experiment. Chapter V is general summary of the work and describes possible research applications and areas of the thesis that require further research. Appendix D to this thesis is classified and can be obtained from Superintendent, Code 0052, Naval Postgraduate School, Monterey, CA 93943-5000 via the Defense Technical Information Center, 8725 John J. Kingman Road, Ste 0944, Ft. Belvoir, VA 22060-6218.

# II. BACKGROUND

## A. THE NERVE CELL

The nervous system is organized assemblies of nerve cells as well as nonnervous cells. Nerve cells, or neurons, are specialized in the generation, integration, and conduction of incoming signals from the outside world or from other neurons [MICH95]. Like all cells within the human body, the neuron has a semipermeable membrane that has holes or "gates" that allow certain molecules to pass in and out. The neuron membrane differs from other cells' membranes in that it has extraordinary electrochemical properties [MATS90]. These extraordinary properties will be discussed later in the thesis. Besides the membrane, the main characteristics of the neuron are the cell body, or soma, the dendrites, the axon and the axon hillock (Figure 1). Besides containing the nucleus, which regulates the general functions of the cell, the soma produces secretory products called neurotransmitters and generates energy for the cell. The dendrites extend from the cell body and make contact with and receive signals in the form of graded potentials from other neurons [MATS90]. These signals serve as the incoming information to the cell. The information from all of the dendrites is integrated in the cell body and may generate an action potential (voltage spike) at the axon hillock [MICH95]. The axon is the conducting path of outgoing information (action potentials) and it eventually attaches to other neurons via a synaptic terminal. A synaptic potential is generated when the action potential reaches the synaptic terminal and electrically charged atoms (ions) of sodium ($NA^+$) and potassium ($K^+$) are allowed to pass through the cell membrane's "gates". These ions cause neurotransmitters to be released into the synaptic cleft (space between synaptic terminal and another neuron) where they then bind to the adjacent neuron, or postsynaptic cell, to produce a graded potential. This graded potential starts the cycle in the postsynaptic cell. Another form of communication is via electrical ephaptic or tight junctions. These electrical ephaptics are significant in relation to pathological states, such as epileptic discharges [BARL93]. Within this framework it can be seen that in groupings or clusters, neuronal networks can be established that allow for communication chemically or electrically.

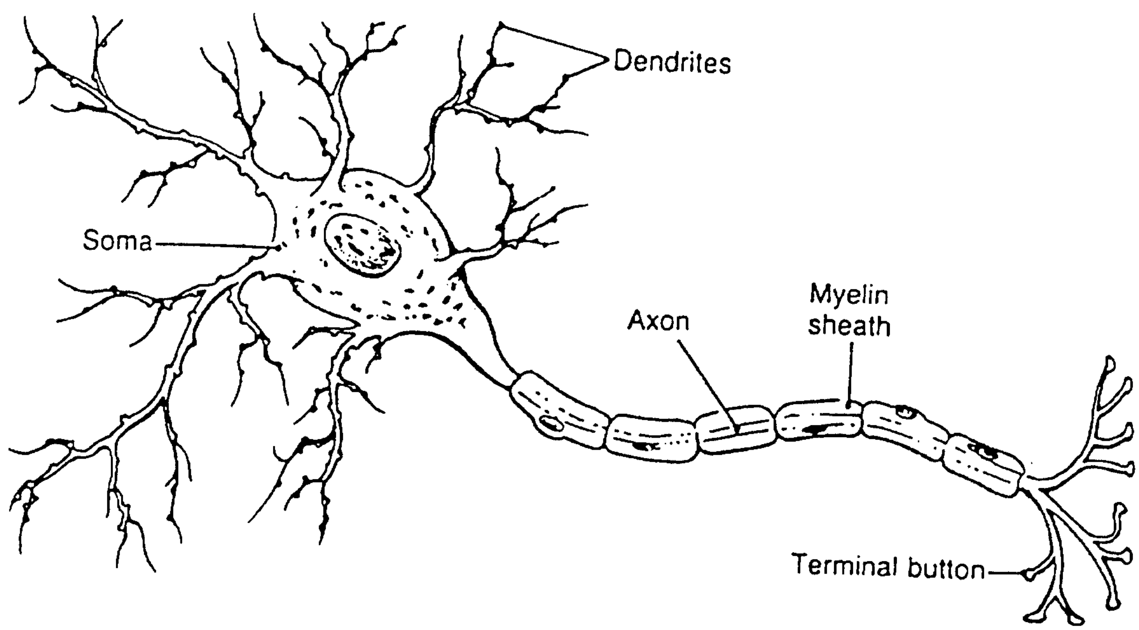


Figure 1. Morphology of a neuron. [MATS90]

The adult human brain can be divided into five basic structures based on their embryonic precursors. One of these structures, the telencephalon, contains the cerebral cortex. The cerebral cortex itself can be grossly subdivided into the frontal, parietal, temporal and occipital lobes (Figure 2). Currently available research indicates that parts of the frontal lobes are involved in the generation of certain emotional states, motor functions, oculomotor control, speech production and foresight. The temporal lobes are associated with audition, auditory and visual recognition and some of the perceptual aspects of language. The parietal cortex contains the somatosensory projection field (cortical representation of the skin senses and kinesthesia) as well as some areas related to visual processing and convergence of visual with somesthetic information. The occipital lobes contain the primary visual cortex [MATS90]. The functions of these structures dictate that this portion of the brain is a likely candidate for exploitation. Within the cortex there are approximately $10^{10}$ neurons [BARL93]. It is the combined synaptic potentials, membrane permeability changes, and the ion currents of these $10^{10}$ neurons that give rise to EEGs [BARL93, MATS90].

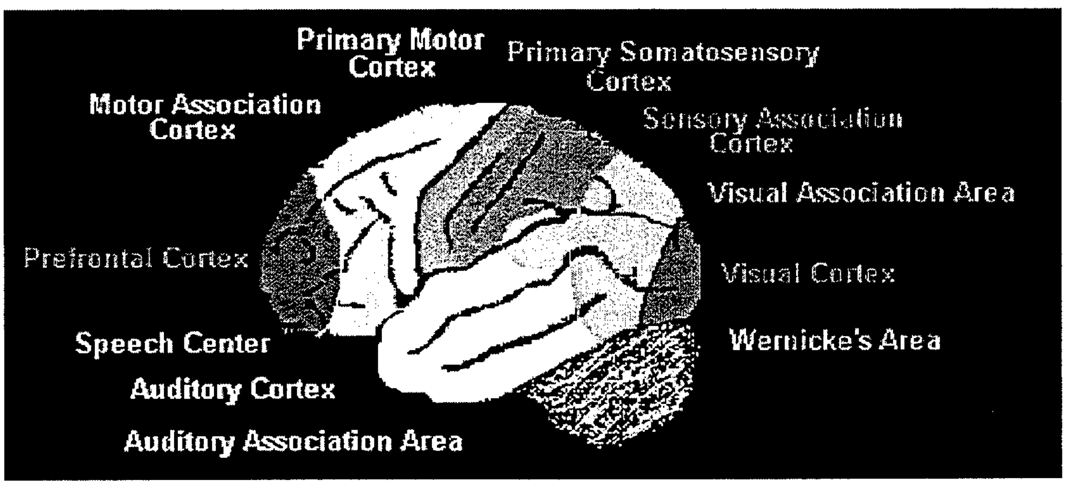

Figure 2. Lateral view of the brain showing major divisions of the cerebral cortex. [CHUD98]

## B. THE ELECTROENCEPHALOGRAM

In 1929, Hans Berger connected two electrodes (small, round, metal disks) to a patient's scalp and detected a feeble current by using a very delicate galvanometer. As electrical amplifiers and recording equipment came into common use, the EEG became a major clinical tool of the neurologist [DEUT93].

Although there have been a few advances in sensor technology, the general method of recording EEGs has changed little for since its introduction. The electrical activity of the brain as recorded from the scalp is modified by the thickness of the scalp, muscles, skull bone and membranes surrounding the brain [DEUT93]. Additionally, the infolding of the cortex complicates reception of the signal [BARL93].

The EEGs that can be recorded from a normal human brain are classified by wavelength and activity state (Table 1). The alpha waves (8-13 HZ) are visible during relaxed, closed eye state. Delta waves (0.5-4 HZ) are associated with deeper stages of sleep. Beta waves (12-22 HZ) are associated with alert states. Theta waves (4-7 HZ) are associated with some sleep states, and with anxiety. Gamma waves (>30 HZ) are believed to be associated with the mechanism of consciousness [BARL93].

| **Classification** | Frequency Range | **Comments** |
|---|---|---|
| **Delta range** | 0.5 – 4 Hz | Young children, deep sleep and pathologies |
| **Theta range** | 4 – 8 Hz | Temporal and central areas during alert states |
| **Alpha range** | 8 – 13 Hz | Awake, relaxed, closed eyes |
| **Beta range** | 13 – 22 Hz | Alert states |
| **Gamma range** | > 30 Hz | Self-awareness |
| **Visual Evoked Potential** | 1 – 300 Hz | Occipital lobe recordings |

Table 1. Classification of Electroencephalogram Signals. [BARL93, COHE95]

Scalp electrodes that are used to record EEGs are placed on certain points on the scalp in accordance with the "10-20 System" of electrode placement. This system is based on the relationship between the location of an electrode and the underlying area of cerebral cortex (Figure 3). The positions are lettered F, T, P, and O for frontal, temporal, parietal, occipital and C for center (Note that there is no central lobe, but this is used for identification purposes). The left hemisphere has odd numbers and the right hemisphere has even numbers associated with it [CHUD98].

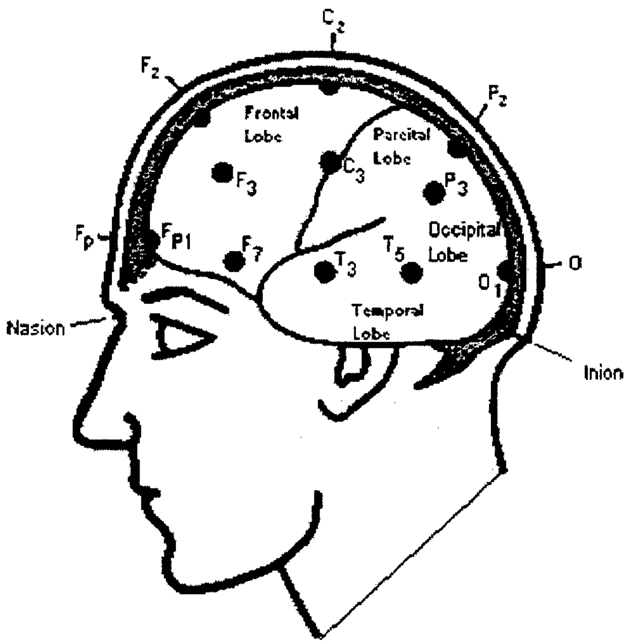


Figure 3. The "10-20 System" of electrode placement. [CHUD98]

The EEG is recorded by attaching electrodes to the scalp using a paste that acts as a conductor. The Electrodes collect the signal, which is then sent to an amplifier, which increases the amplitude up $10^4$. The resulting signal is then displayed on a computer screen or written to a paper via a galvanometer.

The EEG, as well as more sophisticated tools such as functional Magnetic Resonance Imaging (fMRI), are the preferred methods of studying cognitive neuroscience and brain functions. While these tools would be most useful in this thesis, their costs and associated expertise in reading data from the devices is prohibitive. Instead, an indirect method of measuring how the brain was responding was needed. The Kit of Factor-Referenced Cognitive Tests, published by Educational Testing Service, was selected due to its applicability to measuring cognitive behavior, and because there is a large database of results from previous testing.

## C. CURRENT RESEARCH

Dr. F. Terry Hambrecht, head of the Neural Prosthesis Program at the National Institute of Health, was quoted as saying that "DARPA [Defense Advanced Research Projects Agency] has come to us every few years to see if there are ways to incapacitate the central nervous system remotely...but nothing has ever come of it" [PAST97]. The invention of the so-called "death-ray" that would either destroy or incapacitate an individual using only electromagnetic radiation is still only a science fiction dream. Timothy L. Thomas likens the human body to a computer in that they both contain myriad data processors, include chemical electrical activity of the brain, heart and peripheral nervous system, the signals from the cortex and the light sensitive retina and cornea of the eye [THOM98]. Thomas cites a Russian Source Dr. Victor Solntsev, who believes that a computer may be modified to become a weapon by using its energy output to emit acoustics that debilitate the operator [THOM98]. The use of computers as weapons is not supported by any published research, but the possibility of computer-based human effects begun here opens up an entire new realm of information operations.

Douglas Pasternak wrote that a Mr. Eldon Byrd conducted experiments to see if brain waves would move into synchronization with waves impinging on them from the outside. Supposedly he was able to induce the brain to release behavior-regulating chemicals [PAST97]. Again, published work is not available to support these claims.

Within the "mainstream" community, Gloria Calhoun and Grant McMillan of the Armstrong Laboratory, Wright Patterson Air Force Base have published reports of using EEGs as a basis for controlling machines. The system they have used involves the self-regulation of an EEG response. Using biofeedback, subjects learn to increase or decrease the magnitude of the steady-state-visual-evoked-potential (SSVER) in response to an evoking stimulus. These responses are translated via control algorithms into commands that control the operation of a physical device [CALH]. The use of EEGs-based control systems is in its infancy and is not yet utilizable for complex, normal workload, environments. With increasing computing power, application of neural networks, and new discoveries in neuroscience, EEG –based controls in complex systems is a possibility.

Wolpaw, et al, are also involved in research based on voluntary control of the EEG. A user is tasked with moving a cursor on a computer monitor so that it contacts targets that appear randomly at the top, bottom and corners of the monitor. By voluntarily controlling their mu waves, users correctly select the target on 80-95% of the trials [WOLP91]. Again, this method of EEG-based control is in its rudimentary stages at best and will require significant human advances in human factors, bioengineering and computer science prior to real world applications being developed. In its present form might be used only by persons requiring physical assistance.

Training an operator to exert voluntary control over their EEG response is not the only method of utilizing EEGs for control communications. Keirn and Aunon, as previously mentioned, have shown that it is possible to distinguish between various mental tasks using only the EEG, to a high degree of accuracy. In the study, each subject was required to perform five distinct tasks: baseline measurement, complex problem solving, geometric figure rotation, mental letter composing and visual counting. The resulting EEG signal was amplified, and muscle signals were removed. After analysis of the 300 total test cases, it was determined that task pairs were classified 91.8% [KEIR90]. This study suggests that EEGs content can be analyzed, classified and translated into control signals.

In the medical community various devices that alter brain waves are used. D. J. Anderson used Variable Frequency Photo-stimulation (VFP) goggles in the treatment of patients with migraine headaches. The VFP goggles use red Light Emitting Diodes (LED's) to alternatively illuminate the right and left eyes, at rate of 0.5 to 5.0 Hz per eye. The patients used the goggles at the onset of their symptoms and were able to adjust the frequency and intensity of illumination for comfort. Out of the fifty migraines reported, forty-nine were "helped" by the use of the VFP goggles and thirty-six were rated as "stopped" by the goggles. The duration of goggles ranged from 5 to 60 minutes. The mechanism of action of the VFP goggles on the migraine headaches remains unknown, but red stroboscopic lights are known to produce rapid and powerful alpha waves in the occipital cortex [ANDR89]. Although the study used goggles as the delivery method for the stroboscopic light signal, a computer monitor might also be used to transfer the light signal.

The use of lights to cause changes in the brain is known as photic driving (PD). Photic driving is a physiologic response characterized by rhythmic EEG activity elicited by intermittent photic stimulation (IPS) with repetitive flashes mainly over the posterior regions of the head at frequencies of 5-30 Hz [SAKA93]. As the subject is exposed to a train of photic stimuli at a certain frequency, the brain waves become synchronized. This phenomenon has allowed photic stimulation of the EEG to be used as a sensitive tool for the detection of neurological changes. For example, it has been reported that Alzheimer's patients produce a different harmonic response to photic stimulation than normal individuals. In children, the harmonic response to photic stimulation was shown to be a discriminating factor between people who suffer from migraine headaches and those who do not [GIZY97].

Not only is PD useful as a neurophysiological measurement, but some interest has been shown in the dynamics of PD *per se*, and in PD as a research tool for examining the relationship of rhythmic brain activity to mental content and processes [MANG93]. It is this aspect of PD's usage that will be explored in this thesis. If PD can be induced, does the frequency of entrainment correlate to the cognitive states associated with that frequency?

It is interesting to note that the according to the Epilepsy Foundation of America, some epileptics have their seizures triggered by sensory stimuli, including flashing lights. Flash rates of 10 to 20 flashes per second are the threshold for causing seizures in photosensitive patients [EFA]. This has been dramatically evidenced by recent events in Japan where almost 700 children were taken to hospitals with seizures after watching a popular television cartoon. The cartoon scene that triggered the neurological episodes involved a bright-white explosion followed by brilliant red, white and blue lights that flashed like a strobe for about five seconds [SULL97]. The phenomena of television induced seizures might be applicable to computer monitors as well.

The amount of research dealing with the cognitive neuroscience that is being performed today is substantial. The human mind is one of the "last frontiers" and the desire to fathom its depths is strong. As the seat of our emotions, thoughts, bodily function controls and self- consciousness, the brain holds the keys to many aspects of our lives. The research that is being conducted in studying the EEG is an attempt to decipher the functions of the mind via its signals. These signals are being used to attempt the control aircraft, as in Calhoun and McMillan's research, providing assistance to disabled persons as in Wolpaw's research, and in a myriad of "alternative medicine" devices as entertainment through biofeedback and photo-stimulation. As of yet there is no Rosetta

Stone to unlock all of the language of the EEGs. Through increased computing power, better algorithms, and a deeper understanding of neurophysiology, the EEGs signal will eventually be deciphered in its entirety.

In general, certain frequencies in the brain correlate to certain states of mind. Table 1 lists the predominant brain waves and mental states associated with them. As seen from Mangan's research, PD can cause synchronization of brain waves in the alpha band, which is associated with relaxation and meditation. Researchers have produced PD in the theta, beta and gamma bands [GIZY93, MANG93, and SAKA93]. Some research has been done in linking PD and on relationships to memory functioning and to "state" and mood factors [GIZY93]. Shealy and Cox found that photic stimulation in the theta band produced relaxation states in 50-100% of subjects, and others achieved relaxation after stimulation in the alpha band [SHEA90]. Anderson's work showed that photo stimulation could be used to treat migraine headaches in some patients [ANDR89].

With the knowledge that brain waves can be altered using photic stimulation, means of measuring the results of this altering are needed. The EEG has long been an excellent tool in studying the brain, but it does not give an adequate description of the subject's mental state or mood. As an indirect measurement of the overall state of brain function, cognitive evaluation exams might allow us a means of deciphering brain activity without measurement of the EEG. By applying photic stimulation while administering a cognitive exam to the subject, possible effects of PD might be discovered.

## D. POSSIBLE SOLUTION

After a careful review of available literature, the most likely method of affecting a computer user's cognitive behavior is through the application of photo-stimulation via a computer monitor. A program that causes the computer hardware to create a specific photo-stimulation signal must be written, and this computer code must be delivered to the user's computer with minimal interference to the user. It is desired that the signal be inconspicuous or subliminal so as not to distract the user.

Two methods can be used to achieve this end. The first is by writing a virus that targets the video card and driver so as to cause the screen colors and refresh rates to be altered to a desired frequency and color. The second method is to write a small Java applet that runs in the background of any current application. This applet would cause the screen to change to a desired color at a specific frequency. For the scope of this thesis as a pilot study, the latter method is more applicable.

The question of whether PD can cause changes to the EEG of a subject has been answered [GIZY93, SHEA90]. Their research has shown that a subject's mood and level of relaxation can be altered. Cognitive changes in patients with Alzheimer's have been detected using PD, and Anderson's research shows that migraines can be eliminated using PD. With this research as a basis, the author can conclude that if photo stimulation is applied via a monitor, there is potential for photic driving and possible changes in the subject's cognitive functioning. The research however deals primarily with the use of stroboscopic lights in the form of white flashing lights or LED's as the method of photo stimulation. There has been no reported work on the use of computer monitors as the transmission media for photo stimulation. This thesis will attempt to contribute to the photic driving body of knowledge as a whole and to the use of computer monitors as a transmission media in particular.

# III. METHODOLOGY

## A. PROBLEM ANALYSIS

The goal of using a computer monitor to cause photic driving in a user was broken down into two aspects. The first aspect was that a program or application needed to be developed that could not only cause the screen to flash in a desired frequency range and format, but that would also allow for some type of evaluation method to co-exist on the display during the light flashes. Also, having an application that could run within the context of a web browser for potential information operations use was desired. The second aspect of the goal was that the author needed some method of determining whether there was an effect on the user. The cost of a machine that records EEGs as well as the costs of fMRI, etc. were prohibitive. Also, the author did not posses the required expertise to operate and interpret the data from these machines. A low cost, practical and acceptable alternative that measured cognitive behavior needed to be developed.

Java was selected as the computer programming language for this thesis. The language supports the creation of small programs, or applets, that are web based and more importantly, the language also supports threads. Threads were especially important for this study when using the Java Virtual Machine (JVM) because the screen flashing must be given priority for the CPU so that a smooth, regular flash rate is achieved. The Java programming consisted of writing an applet that was initialized and set to run in the background when the web page containing the evaluation test was in the foreground. This applet filled the display, and caused a transition from white to red at various frequencies. This applet came in two forms. The first form, called Flash.java, contained code that caused the screen to flash at a regular frequency of 20 Hz (see Appendix A).

The second form of the applet called Random Flash.java caused the screen to flash in a random pattern (see Appendix A). A webpage, called Cognitive HTML, was written in HyperText Markup Language (HTML) and JavaScript. This webpage was contained the online evaluation tests and support functions such as tracking subject control numbers, submit and reset. The Cognitve.html webpage filled a small portion of the display with the text and images used in the cognitive function evaluation process. These images and text objects ran at a lower priority than the applet responsible for the flashing. The Cognitive HTML webpage used the JavaScript to check for completeness and performed and submission of the responses to the evaluation test as e-mail. This output stream was delayed until the subject had completed the exam in order to decrease any load on the CPU (see Appendix A).

As noted, EEG recording equipment, fMRI, and other tools for measuring brain activity were not considered for use due to numerous reasons. Instead we needed a method that indirectly measured the subjects brain activity. The Kit of Factor-Referenced Cognitive Tests was selected as an indirect measurement tool of cognitive behavior. The Kit is a tool for studying reasoning, verbal ability, spatial ability, memory, and other cognitive processes. It contains 72 tests that have been demonstrated to be consistent markers in studies of 23 cognitive factors [EKST76]. Out of these 23 cognitive factors the author selected two categories of exams which could be used as measurements of specific aspects of cognitive behavior. The additional requirement of an online testing process as well as subject's grasp of the English language, restricted us to a subset of the desirable exams.

## B. EXPERIMENT DESIGN

A number of factors have affected the design decisions of the experiment and the classification of this thesis as a pilot study. One of the most significant is the unique method of delivery for the photo stimulation. As mentioned earlier, no published work documents the use of computer monitors as the transmission media. Also, the use of cognitive evaluation tests to determine if photic driving (PD) has occurred, and has caused changes in the cognitive functioning of the subjects, is untested. As already mentioned, the use of an EEG or fMRI is the most common method of determining the presence of PD but such a machine is not a cost-effective method of evaluation. Although Shealy and Cox used tests to document changes in levels of relaxation caused by PD, this thesis is concerned with changes in cognitive functioning in terms of creativity, alertness, and productivity. Due to the number of unique goals and the methodology used to determine the achievement of these goals, we must consider this a pilot study that will act as a basis for work that will build on the goals achieved, and which will modify the methodology as needed.

The subjects were drawn from a list of volunteers who were all students pursuing graduate degrees at NPS. The subjects were divided into three groups to correspond to the three treatments selected for the experiment. The three treatments chosen for the experimental process were as follows:

**Control Treatment** – Relaxation period treatment of music and darkened glasses for 10 minutes followed by cognitive function evaluation exam with random sequence of flashing in background.

**Light/Sound Treatment** – L/S machine for 10 minutes as part of relaxation period followed by cognitive evaluation exam with random sequence of flashing lights.

**Driving Treatment** – Relaxation period treatment of music and darkened glasses for 10 minutes followed by cognitive function evaluation exam with regular, fixed frequency of flashing in background.

The students were divided into groups of three based solely on the availability of machines/computers. Each group was brought into a small conference room for a brief prior to beginning the experiment. The brief was read with particular emphasis on insuring that no volunteers were epileptics and that none were photosensitive (see Appendix B). After all questions were answered and a final warning concerning epilepsy and photosensitivity, consent forms were read and signed (see Appendix B).

The subjects were then assigned a Control Number to ensure that results were anonymous. They were then given a short Pre-Evaluation questionnaire concerned with their general state of mind and level of wellness (see Appendix B). The subjects' responses on this questionnaire were later compared to the responses on a similar questionnaire given at the completion of the experiment (see Appendix B). The subjects were given a brief on the lab and computer setup and were instructed on how to manipulate the computer pointing device (mouse) in order to answer the exam questions. Further instructions on computer window placement and sizing, how to terminate the background process, maintaining sitting distance from the screen, and the presence of video recording devices were reviewed.

The Relaxation period began with the subjects being instructed to turn their seats around so as to limit their view of the other subjects. Subjects in the Control and Driving groups were instructed to put on headphones and darkened glasses and wait for the signal to start their tape players. The Light/Sound group subjects were given assistance in donning the light sound machine goggles and headphones. The light sound machine provided a countdown timer prior to starting its program that was used to signal the other subjects to start their tape machines. During this ten-minute relaxation period, observations were recorded concerning subjects' movements, expression, and general appearance of relaxation.

Following the relaxation period, the subjects were led into the semi-darkened computer lab and instructed to sit in front of a computer and monitor based on their Control Number. The monitor in front of them had two windows open. A small window containing the cognitive evaluation test was centered in the foreground. A large window started by the Java applet filled the remaining space on the screen (Figure 4). According to their treatment group type (Control, Light/Sound, Driving) the Java applet was flashing randomly or at a specific frequency.

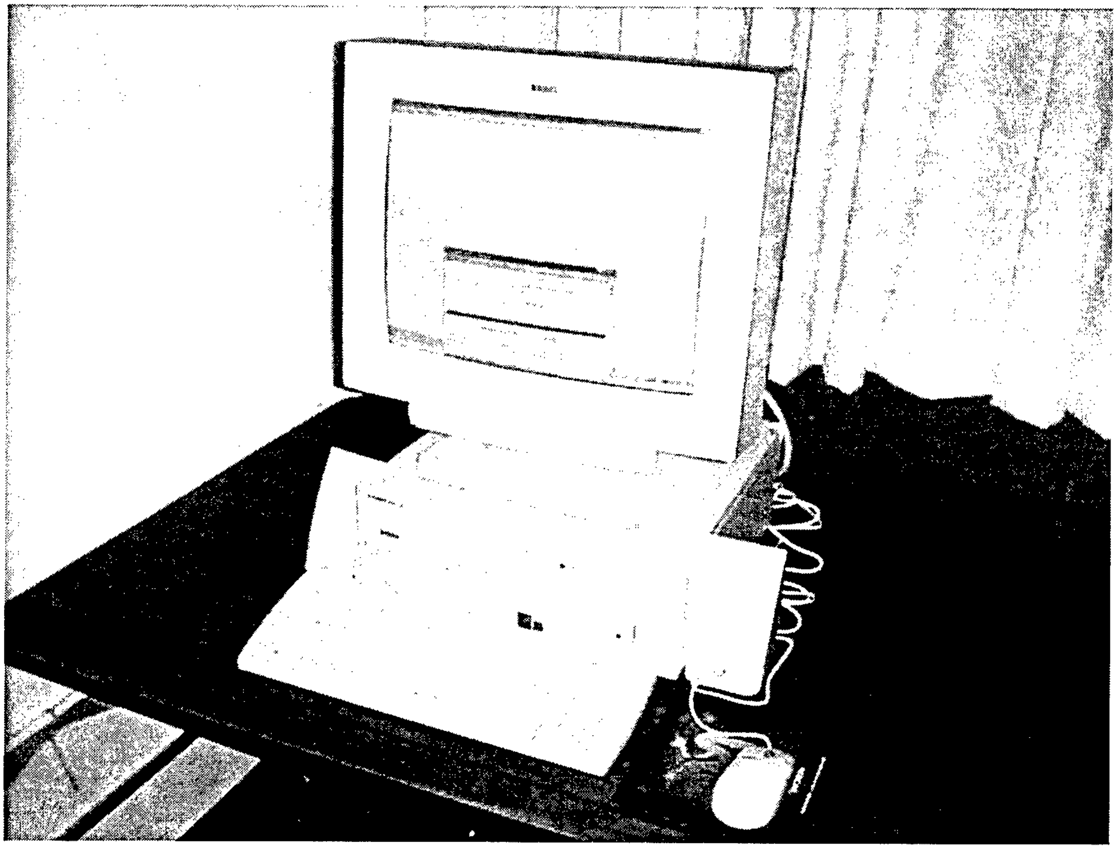
Figure 4. Appearance of monitor screen with both windows.

The cognitive test was presented on the screen as a repeating series of images or as text followed by selection buttons. The following cognitive exams were selected from the Kit of Factor-Referenced Cognitive:

**Closure, Flexibility of (CF) Part 1** – CF is described in the Manual for the Kit as the ability to hold a given visual percept or configuration in mind so as to dis-embed it from other well defined perceptual material. It involves a process occurring in short-term memory whereby a figure is imaged in relation to a surrounding visual-representational field [EKST76]. CF requires a subject to search a distracting set of figures in order to find a given "hidden" figure. The CF test was selected since it requires intense visual concentration directed towards the screen and involves speed in selecting and eliminating figures. Other factors considered were the ability to be adapted to a computer-based test, and that no requirement existed to be proficient in the English language. This test was utilized as Part 1 of the cognitive evaluation period of the study.

**Induction (I) Part 1** – Induction is described in the Manual for the Kit as the factor that identifies the kinds of reasoning abilities involved in forming and trying out hypotheses that will fit a set of data. It appears to be a two-step process requiring both concept formation and hypothesis testing [EKST76]. Induction was selected for this thesis due to the visual nature of the test, its ability to be modified to a computer based test, and its involvement of distinct cognitive reasoning. This test was utilized as Part 2 of the cognitive evaluation period of the study.

The subjects were instructed to fill in their Control Number at the top of the cognitive evaluation test, read the instructions and begin the exam. A timer was started and after 12 minutes, the subjects were instructed to stop the first part of the test and continue with part two. The timer was restarted for an additional twelve minutes. After this time segment was over, the subjects were instructed to press the "submit" button followed by the "reset" button. If the subjects had not yet entered their Control Number, they were prompted to do so again before they could complete the submission. The subjects were then asked to leave the computer lab with the last instruction not to discuss the experiment process with others so as not to taint the volunteer pool. The subjects' answers were emailed to the author for grading and at the completion of the thesis were made available to the subject if they desired them.

## C. SUMMARY

The chosen experiment methodology satisfies a number of the desired goals of the thesis. A careful design of the experiment protocol eliminated many variables and allowed the author to capture as much significant data as possible for the pilot study. The volunteers selected for the study were experienced computer users and although English was not a first language for a few, they were all proficient with the language. Although the entire group of volunteers could not be put through the experiment process at one time, the environment was kept consistent over the course of the study. The choice to include all the subjects in the Relaxation period, and not simply the Light/Sound group, was made to ensure consistency of treatment across the groups.

Through the utilization of inexpensive and commonplace computers with monitors, the author was able to limit the need for funds in carrying out this thesis, and for any practical application that may follow from its results.

The presence of two windows on the monitors was possibly a distraction for the subjects and might have caused them to focus their attention more on the flashing window vice the evaluation test window. The two-window system was utilized in order to ensure that the flashing screen occupied as much of the subjects' field of view as possible, and that the thread controlling the flashing had priority of execution. Other methods considered included embedding the screen flashing into the background of the webpage containing the evaluation tests. This method was rejected because the screen flashing thread needed to take precedence over any other running thread which could not be assured if the code responsible for the flashing was embedded in the evaluation test webpage. Operationally the best screen presentation may be the Java applet with the screen flashing embedded in applet due to the virtual universality of the JVM in web browsers.

The selection of the Kit of Factor-Referenced Cognitive Tests as the evaluation tool assisted in meeting the goal of empirically showing the presence of the effects of photo stimulation on the subjects' cognitive performance. While taking the cognitive evaluation tests, the subjects were video taped and their performance on each part of the test was associated with their body position, attitude, and degree of comfort. The scores for the groups can be compared to each other to determine the presence of any significant alteration in performance.

Careful analysis of the observations made during the relaxation period, the observations made from the video taped cognitive evaluation test period, test scores, and subjects' responses on the Pre- and Post-Evaluation questionnaires is imperative in order to have reliable results. Inclusion of the video tape recording was significant in that any direct physical effects of the flashing could be observed, and if necessary, reviewed. Controlling the conditions between and within the groups was accomplished through the homogeneity of the different phases. These factors and conditions allowed us to test the hypothesis of the pilot study which, simply stated, was to determine if changes could be made to the cognitive functioning of a subject via PD.

# IV. RESULTS

## A. TREATMENT #1

Treatment #1 consisted of a ten minutes session with the Light/Sound machine (20Hz), followed by the cognitive evaluation period with a randomly flashing background. The results for this group can be found in Appendix C and are summarized as follows:

### Pre-Questionnaire Summary

On a scale of 1 to 5 (1 being the lowest and 5 the highest) this group rated themselves on average as a 4 in Computer abilities, 4.3 in overall cognitive abilities, 4 in current state of mind, and 4.1 in current physical state. These self-ratings, except the computer ability rating, were the highest out of all the groups. The majority, 71%, of the subjects in this group participated in the experiment during the afternoon.

### Relaxation Results

Objective observations during the relaxation period were that 72% of the subjects remained quiet, 42% were still, and 57% appeared to be relaxed. These subjects tended to display more movement than the others, and were more likely to appear tense. The overall impression was that movement was higher and feelings of relaxation were lower.

Subjective observations from the Post-Evaluation Questionnaire covering the relaxation period spanned from "relaxed" to "on-edge" and "lethargic". One of the subjects also stated that vision in his right eye was out of focus for some time after exposure to the L/S machine. This loss of vision was unexpected and review of the light sound machine documentation does not suggest this as a side effect to use of the machine.

The overall subjective comments on the effects of the relaxation period were too mixed to categorize.

**Cognitive Evaluation Results**

Videotaping the subjects as they took the online evaluation was the method utilized to collect the cognitive evaluation observations for all groups. The video camera was placed so that the view recorded was from the subjects' side and included the subject from the waist up, including the subjects' hands, and the computer terminal. See Figure 5 for photograph of a typical cognitive evaluation period setup. Due to a technical problem data for three of the seven subjects in this group was not usable. This group had the same number of subjects displaying movement as those remaining still.

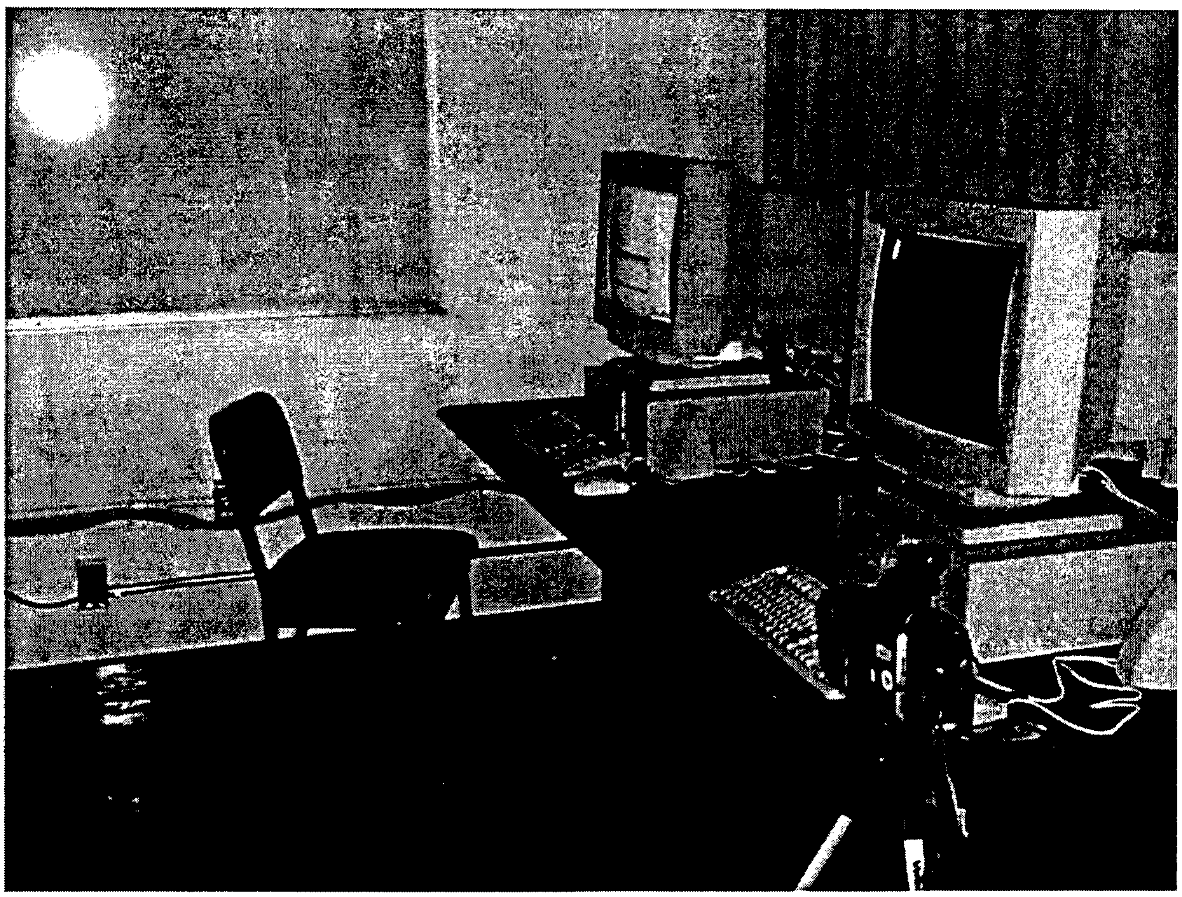

Figure 5. Laboratory setup for cognitive evaluation period.

Objective observations of the data available indicate that this group of subjects appeared the least comfortable of all the groups at 50%. The group also appeared to be about 50% still, and 75% maintained the proper distance from the terminal screen. The average number of times these subjects moved their bodies as well as their heads was lower than that of the other groups. The overall impression was that these subjects were concentrating, with little extraneous movement.

This group answered an average of 8.4 questions on Part 1 with an average of 4.3 correct answers (standard deviation of 5.47, 2.05 respectively). On Part 2, this group answered an average of 14 questions and averaged 11.7 correct with standard deviations of 0.81 and 1.97 respectively.

**Post-Questionnaire Summary**

During the relaxation period, 71% of the subjects in this group reported that both their mental and physical states were affected by the Light/Sound machine exposure. Of the group, 2 indicated that the Light/Sound machine treatment left them relaxed and 1 reported that they were alert and on edge. One subject reported out of focus vision in the right eye that lasted for a few minutes after the Light/Sound machine treatment. Their average state of mind and average physical state were 3 and 3.3 (out of 5).

For the evaluation period, 100% reported that their state of mind was affected and 57% reported that their physical state was affected. Tired eyes and frustration were the main comments for this group. Reported physical states improved from an average of 3.3 after the relaxation period to an average of 3.6 after the cognitive evaluation period. During the period 3-24 hours after their participation in the experiment, 29% reported some sort of residual effects. Two members of this group reported headaches, and as previously mentioned one complained of vision problems.

## B. TREATMENT #2

Treatment #2 consisted of a ten-minute relaxation period with darkened glasses and soft music, followed by the cognitive evaluation with the driving background (20Hz). The results for this group can be found in Appendix C and are summarized as follows:

### Pre-Questionnaire Summary

This group rated themselves the highest of the three groups in computer abilities at 4.2. They rated themselves at an average of 3.6 for cognitive abilities, 3.9 for current mood and state of mind, and 3.8 for physical state. This group had half its members participating in the study during the afternoon and half in the morning.

### Relaxation Results

Objective observations for this group indicated that 80% remained quiet, 70% remained still and 90% appeared relaxed. This group had at least one subject that fell asleep with another that was possibly asleep as well. For most subjects, there were small to no movements observed and one subject appeared to be bored by the proceedings. Overall this group was observed to be relaxed and quiet.

Subjective comments recorded on the Post-evaluation Questionnaire included "more at ease, lower heart rate", "drowsy and tired" and one comment that the relaxation period put them in a "good frame of mind". No subjects complained of tenseness, lethargy, or altered physical state due to this phase. Overall impression of the subjective comments are that the subjects were very relaxed and quiet.

### Cognitive Evaluation Results

The observation covering the cognitive evaluation phase showed that 90% of the subjects in this group were comfortable and 50% remained still. This group had the highest average head and body movements at an average of 38.8 head movements and an average 11 body movements. This group had the lowest percentage, 30%, of subjects who maintained the correct distance from the monitor.

On Part 1 of the cognitive evaluation, this group averaged 4.8 questions answered with an average of 5.1 of these question answered correctly, which was the highest average of the three groups. The standard deviations for Part 1 were 4.83 and 3.17. Out of the average 13.7 questions answered on Part 2 of the cognitive evaluation, an average 11.4 were answered correctly with standard deviations of 2.36 and 2.84 respectively.

**Post-Questionnaire Summary**

This group had the lowest subjective ratings of the groups for effects of the relaxation period on their state of mind and physical states. They reported that 70% of the subjects' states of mind were affected and only 50% of the subjects were physically affected. Out of the group, 3 reported that they felt relaxed after the relaxation phase. Their reported average mental and physical states were 3 and 3.2 respectively.

Only 50% of this group reported effects on their state of mind due to the cognitive evaluation period, which was the lowest percentage of the groups. During the cognitive evaluation period, 2 subjects reported feelings of frustration and 1 subject reported an increased heart rate due to a nervous physical state. Effects on their physical state were reported by 40% and included a comment concerning "residual effects" felt 3-24 hours after participation in the study. There was no reported change in their state of mind from the relaxation period to the post-evaluation period and only a change from an average of 3 to an average of 3.2 in their physical state over the same time frame. No members of this group reported any headaches and only 1 reported feeling "queasy and unable to focus".

## C. TREATMENT #3

Treatment #3 consisted of a ten-minute relaxation period with darkened glasses and soft music, followed by the cognitive evaluation with a randomly flashing background. The results for this group can be found in Appendix C and are summarized as follows:

**Pre-Questionnaire Summary**

This group reported themselves as the lowest average of all the groups for computer abilities with an average of 3.9. Their reported overall cognitive abilities average of 3.6, mood average of 3.6, state of mind average of 3 and physical state average of 3.1 were also the lowest self-evaluations of all the groups. Sixty-two percent of this group participated in the study during the afternoon hours.

**Relaxation Results**

Objective observations for this group during the relaxation period indicated that 88% remained quiet and 88% remained still both of which were the highest percentages of the groups. Seventy-five percent appeared relaxed. This group displayed similar signs that Treatment group #2 displayed. They were quiet, relatively motionless, and a few subjects were possibly asleep. One of the subjects appeared tense and uncomfortable during this phase. The overall observation for this group is that they were relaxed and quiet.

Subjective comments for the relaxation period sustain the objective observations in that the subjects reported that they were "relaxed", "less tense", "tired", and "refreshed". There were no complaints of altered physical states or tenseness for this phase.

**Cognitive Evaluation Results**

The objective observations made during the cognitive evaluation period show that all the subjects in this group appeared comfortable but only 25% of them remained still. Body and head movement averages were 10.5 and 33.9 respectively. Half of the subjects maintained the correct distance from the monitor. One subject did not appear comfortable at first but this was attributed to the fact that he had momentarily sat in front of the wrong computer.

This group answered the fewest average questions on Part 1 of cognitive evaluation at only 7, with a standard deviation of 4.84. They were correct on average about 4.3 times with a 3.69 standard deviation. On Part 2 of cognitive evaluation, this group had the highest average of questions answered, 14.1, and the highest average of correct answers, 12.5.

**Post-Evaluation Summary**

Percentages of 88% and 75%, which were the highs among the groups, were reported by this group for effects on their state of mind and physical state due to the relaxation period. Four subjects reported feelings of relaxation and of being refreshed and 1 subject reported that they felt tired. Their average physical state and state of mind were 3 and 2.75, respectively.

During the cognitive evaluation period, effects on their state of mind were reported by 88% of the subjects. This group had the lowest percentage, 25%, of reports that their physical state was effected by the cognitive evaluation period. Their reported state of mind following the cognitive evaluation period was the same as that reported following the relaxation period, but their average physical state over the same period improved from 2.75 to 3.25. A high of 38% reported that they felt effects of headaches or queasiness 3-24 hours after participation in the study.

## D. ANALYSIS OF RESULTS

### Analysis Within This Experiment

During the relaxation period, the Light/Sound group was the least relaxed of the three groups. This may be attributed in part to the fact that this was a first time exposure to a Light/Sound machine. Due to the quiet nature of the music played to the other groups and the lack of visual stimuli, they reported a greater level of relaxation.

The cognitive evaluation period observations indicate that the screen flashing, in particular the random pattern flashing, caused physical problems for some of the subjects. No headaches were reported by the group exposed to the steady, 20Hz driving flashing, but a full one third of the subjects in the other groups reported mild to severe headaches after exposure to the randomly flashing screen.

The questions in Part 1 of the cognitive evaluation, which evaluated Flexibility of Closure, were labeled the most difficult in the online evaluation period. Overall the groups answered an average of only 7.9 of the 16 questions and were correct on an average of only 4.5 of these. The Flexibility of Closure test is very visually intensive in nature. It required intense concentration directed toward images on the screen for long periods of time. It is believed that the presence of the screen flashing directly distracted the subject, thus causing the low numbered answered and low number correct.

On Part 2 of the cognitive evaluation, which evaluated Induction, the subjects performed better. The groups answered an average of 13.9 questions out of 16, and were correct on 11.9 of these. The Induction test, unlike the previous test, did not require intensely staring at the images. Subjects were likely to have moved a little further away from the monitor at this time since they did not have to concentrate as intently on the screen images and some subjects were observed counting on their fingers to assist them in determining the correct answer.

**Difference of Means Significance Test**

The Difference of Means Significance Test was performed on each part of the online evaluation. For the calculations, there were two degrees of freedom in the numerator and 22 degrees of freedom in the denominator. Table 2 depicts the calculations performed for this test.

The calculated F is in each of the 4 cases, less than the critical values of the F distribution for $\alpha = .10$, $\alpha = .05$, or $\alpha = .01$. These results show that there was no significant difference between the performance of the groups on the two cognitive evaluation tests. These results were supported by Chi- Square test for *k* independent samples over the same data.

Although these calculations show that the cognitive evaluation performances were not significantly different due to the photo-stimulation, they do not prove that there was no effects produced by the photo-stimulation. The observation data that was gathered as well the subjects' own responses on the questionnaires indicate that the photo-stimulation did have some effects.

| | Part 1 Answered | Part 1 Correct | Part 2 Answered | Part 2 Correct |
|---|---|---|---|---|
| Degrees of Freedom, Numerator | 2 | 2 | 2 | 2 |
| Degrees of Freedom, Denominator | 22 | 22 | 22 | 22 |
| Within | 553.81 | 211.83 | 60.98 | 113.83 |
| Between | 10.03 | 4.17 | 0.87 | 5.53 |
| Variance Estimate, Within | 25.17 | 9.63 | 2.77 | 5.17 |
| Variance Estimate, Between | 5.01 | 2.09 | 0.43 | 2.77 |
| Calculated F | 0.199 | 0.217 | 0.156 | 0.535 |

Table 2. Calculations for Difference of Means Significance Test.

# V. CONCLUSIONS

## A. SUMMARY OF WORK

The Difference of Means Significance test and the Chi-Square test for *k* independent samples indicate that the author cannot prove that significant effects were reflected in the cognitive evaluation due to the photo stimulation. These same tests do not disprove that the photo-stimulation treatment caused some effects. Objective and subjective reports indicate that treatment with the light sound machine produced more observable expressions of tenseness and discomfort during the relaxation period. Subjects in the Light/Sound treatment group were the only ones to report headaches during the relaxation period. One of these subjects repeatedly adjusted the volume and intensity of the light due to the discomfort it produced. Since the Light/Sound machine is a device that is used exclusively for photo stimulation, it is apparent that some effects on the cognitive functioning of the subjects in this group did occur.

Observations during the evaluation period indicated that the majority of the subjects gradually increased their distance from the monitor during the online evaluation period. Since all of the subjects were exposed to some form of a flashing background, this phenomenon can probably be attributed to the discomfort caused by the flashing. The notion that the movement away from the monitor was a sign of relaxation was rejected based on the subjects' responses on the Post-Evaluation Questionnaire.

Subjects' responses and observations made during the cognitive evaluation period indicate that the random screen flashing did adversely affect a number of the subjects in the Light/Sound machine and Control groups. A number of these subjects reported that they experienced headaches caused by the cognitive evaluation period. These occurrences are even more significant when compared to the experiences of those subjects in the Driving group. The Driving group subjects, who received a constant rate of flashing, did not report any headaches either during or after the cognitive evaluation period. This data suggests that the random flashing did cause a change in the cognitive functioning of the subjects. This conjecture may have implications for those who design virtual environments in some instances where computing power, distributed systems and protocols may not permit adequate refresh rates for an application. Another area where this conjecture might be applicable is in the development of applications where monitors are filled with constantly changing windows. These constantly changing windows may cause unintended effects in a user.

Through careful design of an experimental protocol the author eliminated many undesirable variables. Careful observation, recording and evaluation at each phase were critical to insure a quality study. Measurement of alterations in cognitive functioning while exposed to photo stimulation must occur in a tightly controlled environment. Consistency between and amongst the samples was guaranteed through a careful empirical design and vigilant attention to detail. One of the more significant issues encountered was determining the method of evaluating any change in cognitive functioning. This issue was partly overcome by using selected portions of the Kit of Factor-Referenced Cognitive Tests. The selected tests were applicable to the cognitive factors that would most likely be affected by PD, and they were easily transformed into usable web-based evaluations. The use of the Pre- and Post-Evaluation Questionnaires was also necessary to insure that any changes in cognitive functioning not detected by the cognitive evaluation tests would be properly recorded and evaluated. The subjects' responses to the questions and their comments enabled some data that may have been missed by simply the cognitive testing procedure to in fact be captured and analyzed. It is surmised that in this instance, the cognitive evaluation data, while being correct, was insufficient to properly evaluate all of the possible effects of the photo-stimulation.

Hiding the photo stimulation from the subject was only partially successful. A number of the subjects reported that they observed the flashing pattern in the background. It is surmised that most, if not all, of the subjects were to a certain extent aware that there was indeed some event occurring in the background. The level of luminance may possibly need to be adjusted so that the flashing might be completely hidden from the subject. Such a reduction in luminance of the flashing may not be adequate to elicit PD and so any change would have to be thoroughly studied prior to implementation. Since this thesis did not directly test for the presence of PD in the subjects, there is the possibility that the photo stimulation provided to the Driving group was not adequate to elicit the driving response. If the photo-stimulation proved inadequate in eliciting the PD response, possible reasons might include the level of luminance, field of view covered and duration of photo stimulation treatment.

Through the necessity of fiscal constraint, and to insure widespread utilization if the results of the thesis proved usable, finding an inexpensive method of delivering photo-stimulation is needed. Since the author was attempting to affect changes in computer users, limiting the selection of delivery methods to a desktop computer and its peripherals was considered a straightforward approach to solving the problem. The presence of computers and the associated monitor is commonplace throughout the Department of Defense and even most of the civilian sector. The small size and the machine independence of the Java programming language insures that the applet could be sent virtually to any computer and run correctly once executed by the user. Costs incurred during the development and subsequent utilization of the thesis were minimal. Potential costs that would be passed on to a user, through retrieval, installation and execution of the code would also be minimal.

As noted earlier, it has been shown that a subject's mood can be affected by exposure to photo-stimulation [GIZY97]. These changes in mood occur at specific frequencies of photo-stimulation. By selecting a target frequency of brain waves that is associated with high levels of alertness and active thinking, this thesis attempted to cause PD at that frequency. Although the cognitive evaluation results did not prove that changes did occur, they also did not disprove that change occurred. The small sample size was probably the most significant factor that limited full assessment of the actual presence or absence of changes in the subjects' cognitive functioning. The small sample size and utilization of only specific parts of the tests form the Kit of Factor-Referenced Cognitive Tests combined with the unique, computer based presentation of the tests prevent the author from comparing the results from this thesis to results from other applications of the Kit's tests. This will hopefully be addressed by follow on research by increasing the sample size and by expanding the time allotted for the subjects to participate.

## B. FURTHER RESEARCH APPLICATIONS

The potential for use of PD is immense if it can be induced via desktop computer monitors. Different aspects of the brain wave patterns could potentially be affected by goal-specific PD frequencies in virtually any setting whether shipboard or ashore. In situations where high levels of stress and fatigue are commonplace, such as a Combat Information Center, PD could be utilized to increase alertness and stress. Other applications of goal-specific PD frequencies include increasing student or general user creativity and productivity.

The Department of Defense is committed to research that explores the use of simulations and virtual environments as cost cutting measures to replace real world training. Total immersion environments and those virtual worlds that are experienced through head mounted displays or goggles are situations where PD may be utilized. The field of view of these devices that are covered by the virtual images is higher than what can be accomplished using a single monitor and as such PD effects may be more likely to occur. One potential drawback is the present state of the art in head mounted display fidelity.

For situations where PD is not warranted or would cause damage, disabling Java would be a sufficient method to prevent transmission of PD containing applets. Filtering of the contents of webpages, and specifically attached Java applets or mobile code, at the firewall might also be a potential method to prevent undesirable PD transmissions. Since the flashing could be caused by alterations to the video card and/or video drive, the flashing code could also be encoded as part of a virus that targets this card or drive. Depending on the size and structure of the virus produced, virus protection software would probably be an adequate defense in this case.

## C. RECOMMENDATIONS FOR FURTHER RESEARCH

To determine if PD is actually occurring, rather than simply looking for potential changes caused by it, further studies should include the use of an EEG or if possible an fMRI. These devices could be used to prove that PD via a specific transmission media was present. As noted previously the cost, availability and technical expertise required in utilizing these devices precluded their use in this study, and may limit their use in future studies.

A full factorial design should be implemented as the next logical step in a future study. By adding a treatment consisting of Light/Sound machine followed by the driving frequency application, more variables could be eliminated. Also, in order to increase the number of scores on the cognitive evaluation for comparison purposes, a large number of subjects should take the online evaluation without any relaxation treatment or flashing in the background. These scores could then be directly compared to those scores achieved by the study subjects. Also, any increase in sample size would significantly benefit follow on research. By utilizing full sets of test from the Kit of Factor-Referenced Cognitive Tests, comparisons could potentially be made with other studies as long as the effects of the online presentation of this thesis' tests could be statistically eliminated.

The use of larger monitors, or even as mentioned earlier, virtual reality goggles, to increase the field of view coverage might be useful. Current methods of inducing PD practically fill the field of view of the subject. The online evaluation period utilized 21" monitors but even this size did not fill the subjects' field of view. The use of a semi-darkened room in which the cognitive evaluation period was conducted is an artificial environment, but for the purposes of this thesis as a pilot study, decreasing the ambient lighting in the room were considered necessary to increase potential for effects of the photo-stimulation.

This study explored the use of a 20Hz driving frequency in both the Light/Sound machine treatment applied during the relaxation period and as the background flashing rate for the Driving group applied during the cognitive evaluation period. This frequency was intended to promote alertness and "faster thinking" in the subjects. Other frequencies, such as the alpha (8 - 13Hz) or theta (4 - 8Hz) frequencies might be studied as potential frequencies in hopes of causing relaxation or creativity.

In this study, all of the subjects in the volunteer pool were graduate students at NPS. Broadening the pool, to include more international students, non-students and perhaps the general public, would significantly increase the sample size and would give a more diverse group to the empirical study. The time required for a subject to complete the entire experiment was approximately 1 hour. Many students were interested in participating in the study, but could not due to conflicting class and lab schedules. Extending the time required to participate would allow for more thorough testing to be performed, but might potentially limit the number of volunteer subjects.

Associated with the time required to participate in the study is the number of cognitive factors that were tested. Increasing the number of factors in question increases the amount of time to participate which unfortunately my preclude participation by some volunteers. In this thesis, 2 cognitive factors were explored, Flexibility of Closure and Induction. In follow on work, selection of a single factor for which to test, might allow for a more intensive and revealing exploration of that cognitive factor. The chaining of tests for the single cognitive factor might contribute to a "learning" of the test, but this phenomenon could be accounted for in the analysis.

As noted earlier, the Driving group did not experience headaches caused by the flashing background. Subjects from both the Light/Sound machine and Control groups reported headaches due to the cognitive evaluation period. The differences reported by the subjects exposed to the different forms of the flashing suggest that further research is required to fully understand and possibly utilize this phenomenon. The adopting of a full factorial design might be useful in exploration of this phenomenon.

# APPENDIX A. COMPUTER CODE

The first part of this appendix contains the Java programming code for the Flash.java and the Flash.html webpage that calls this applet. Part two of this appendix conatains the Random Flash.java applet and the RandomFlash.html webpage that calls this applet. The third part of this appendix contains the HTML and Javascript code for the Cognitive.html webpage that contains the cognitive evaluation tests. The images used in the cognitive evaluation tests are not included due to licensing restraints.

**Part 1 Flash.java and Flash.html**

```
/**
 * Filename:  Flash.java
 * Date:  Nov 1998
 * Thesis Project for Robert Peterman
 * Compiler: JDK 1.2
 */

import java.awt.Graphics;
import java.awt.Image;
import java.util.*;
import java.awt.Color;
import java.awt.Font;
import java.awt.*;
import java.applet.Applet;
import java.io.*;


/**
 *
 * Flash Class is the applet that contains the background
 * flashing at a specific hertz.
 * Created by Robert Peterman, Nov. 1998
 *
 */
public class Flash extends java.applet.Applet implements Runnable {
        Image backgrounds[] = new Image[1];
        Image currentImage;
        Thread screenFlash = null;
        final int standard = 17;
        final int strdx =28;
        int x = 0;
        int y = 0;
        boolean test = true;



/**
 * The init() method adds the images
 *
 * param    none.
 * return   none.
 * exception  none
 */
public void init(){
        backgrounds[0] = getImage(getCodeBase(), "bgred.gif");
```

```
        currentImage = backgrounds[0];

}//end init()



/**
 * The start() method check to see if a new thread has been created.
 * If not, it creates a new Thread, gives it the name screenFlash,
 * sets the priority to the maximum value allowed, and then starts
 * the thread.
 *
 * param    none.
 * return   void.
 * exception none
 */

public void start(){
        if (screenFlash == null){
                screenFlash = new Thread (this, "screenFlash");
                screenFlash.setPriority(Thread.MAX_PRIORITY);
                screenFlash.start();
        }//end if
}//end start()



/**
 * The run() method, is invoked when the thread is started. It repaints
 * the screen to either redgb or clears screen and then sleeps for (standard)ms
 * and (strdx)ms.
* param    none.
 * return   void.
 * exception InterruptedException
 */

public void run(){
        Thread myThread = Thread.currentThread();
        while (screenFlash == myThread){
                currentImage = backgrounds[0];
                repaint();
                try{
                Thread.sleep(standard);
                }catch (InterruptedException e) {}

                test = false;
                repaint();
```

```
                try{
                        Thread.sleep(strdx);
                }catch (InterruptedException e) {}
        }//end while
}//end run()


/**
 * The stop() method overrides the Applet's stop method, not the Thread's.
 *
 * param    none.
 * return   void.
 * exception  none
 *
 *
public void stop(){
        if (screenFlash != null) {
                screenFlash = null;
        }//end if
}//end stop()


/**
 * The paint(Graphics screen) method paints the background to the screen.
 *
 * param    Graphics screen.
 * return   void.
 * exception  none
 */
public void paint (Graphics screen) {
        setBackground(Color.white);
        if (currentImage != null){
                if (test){
                        screen.drawImage(currentImage, x, y, this);
                } else
                        screen.clearRect(0, 0, size().width, size().height);
                        test = true;
        }//end if
}//end paint()


/**
 * The update(Graphics screen) method overwritten to only call paint.
 *
```

```
 * param    Graphics screen.
 * return   void.
 * exception ???
 */
public void update(Graphics screen) {
        paint(screen);
}//end update()


}//end Flash.java class
```

```
<!---This is the Flash.html web page that calls the Flash.java applet and sets the
<!---size of the applet window.
<HTML>
<HEAD>
<TITLE>The ScreenFlash Page</TITLE>
</HEAD>
<BODY>
<BR>
<APPLET CODE="Flash.class" WIDTH=1200 HEIGHT=800>
If your browser does not support Java you will not see the flashing!
</APPLET>
</BODY>
</HTML>
```

**Part 2 Random Flash.java and Random Flash.html**

```
/**
 * Filename:  Random Flash.java
 * Date:  Nov 1998
 * Thesis Project
 * Compiler: JDK 1.1.6
 */
import java.awt.Graphics;
import java.awt.Image;
import java.util.*;
import java.awt.Color;
import java.awt.Font;
import java.awt.*;
import java.applet.Applet;
import java.io.*;

/**
* R_Flash Class is the applet that contains the background
 * flashing at a random hertz.
 * Created by Robert Peterman, Nov. 1998
*/
public class R_Flash extends java.applet.Applet implements Runnable {
        Font f = new Font ("TimesRoman", Font.BOLD, 26);
        Image backgrounds[] = new Image[1];
        Image currentImage;
        Thread screenFlash = null;
        int x = 0;
        int y = 0;
        boolean test = true;
        //linked list to hold random times for flashing
        Vector randomList = new Vector();
        //Long Objects to put in Vector
        Long random1 = new Long (20);      //50Hz
        Long random2 = new Long (200);     //5Hz
        Long random3 = new Long (22);      //45Hz
        Long random4 = new Long (167);     //6Hz
        Long random5 = new Long (100);     //10Hz
        Long random6 = new Long (33);      //30Hz
        Long random7 = new Long (40);      //25Hz
        Long random8 = new Long (125);     //8Hz
        Long random9 = new Long (38);      //26Hz
        Long random10 = new Long (63);     //16Hz
        Long temp = new Long(1000);
        long next_rand;
```

```
/**
 * The init() method adds the background image and puts random
 * frequencies into LinkedList
 * param    none.
 * return   none.
 * exception  none
 */
public void init(){
        backgrounds[0] = getImage(getCodeBase(), "bgred.gif");
        currentImage = backgrounds[0];
        randomList.addElement(random1);
        randomList.addElement(random2);
        randomList.addElement(random3);
        randomList.addElement(random4);
        randomList.addElement(random5);
        randomList.addElement(random6);
        randomList.addElement(random7);
        randomList.addElement(random8);
        randomList.addElement(random9);
        randomList.addElement(random10);
}//end init()


/**
 * The start() method check to see if a new thread has been created.
 * If not, it creates a new Thread, gives it the name screenFlash,
 * sets the priority to the maximum value allowed, and then starts
 * the thread.
 * param    none.
 * return   void.
 * exception  none
 */
public void start(){
        if (screenFlash == null){
                screenFlash = new Thread (this, "screenFlash");
                screenFlash.setPriority(Thread.MAX_PRIORITY);
                screenFlash.start();
        }//end if
}//end start()


/**
 * The run() method, is invoked when the thread is started. It repaints
```

```
 * the screen to bgred or white and then sleeps for (random#)ms.
 * param    none.
 * return   void.
 * exception  InterruptedException
 */
public void run(){
        Thread myThread = Thread.currentThread();
        while (screenFlash == myThread){
                temp = ((Long) randomList.firstElement());
                randomList.removeElementAt(0);
                next_rand = temp.longValue();
                randomList.addElement(temp);
                currentImage = backgrounds[0];
                repaint();
                try{
                        Thread.sleep(next_rand);
                }catch (InterruptedException e) {}
                test = false;
                repaint();
                try{
                        Thread.sleep(10);
                } catch (InterruptedException e) {}
        }//end while
}//end run()


/**
 * The stop() method overrides the Applet's stop method, not the Thread's.
 * param    none.
 * return   void.
 * exception ???.
 */
public void stop(){
        if (screenFlash != null) {
                screenFlash = null;
        }//end if
}//end stop()




/**
 * The paint(Graphics screen) method paints the background to the screen
 *
```

```
 * param    Graphics screen.
 * return   void.
 * exception  none
 */
public void paint (Graphics screen) {
        setBackground(Color.white);
        if (currentImage != null){
                if (test){
                        screen.drawImage(currentImage, x, y, this);
                } else
                        screen.clearRect(0, 0, size().width, size().height);
                        test = true;
        }//end if
}//end paint()


/**
 * The update(Graphics screen) method overwritten to only call paint.
 * param    Graphics screen.
 * return   void.
 * exception  none
 */
public void update(Graphics screen) {
        paint(screen);
}//end update()

}//end Flash.java class
```

```
<!---This is the Flash.html web page that calls the Flash.java applet and sets the
<!---size of the applet window.
<HTML>
<HEAD>
<TITLE>The Random Screen Flash Page</TITLE>
</HEAD>
<BODY>
<BR>
<APPLET CODE="R_Flash.class" WIDTH=1200 HEIGHT=800>
If your browser does not support Java you will not see the flashing!
</APPLET>
</BODY>
</HTML>
```

**Part 3 Cognitive.html**

```
<html>

<head>
<meta name="GENERATOR" content="Rocketman">
<title>CognitiveHTML</title>
<script LANGUAGE="javascript">

<!--
function goIn(){
  window.open ("Flash.html", "Applet",
"toolbar=0,location=0,directories=0,status=0,menubar=0,scrollbars=0,resizable=0,width=
400,height=400");
  }//end goIn()

function checkIt(){
        var strval = document.emailform.controlNum.value;
        var intval = parseInt(strval);
        if (0 < intval && intval < 100) {
                return(true);
        } else {
                alert("Please enter or renter your Control Number at top of form");
                return(false);
        }//end if else
}//end checkIt()

// -->

</script>
</head>

<body>

<form method="POST" enctype="text/plain" action="mailto:peterman@cs.nps.navy.mil"
name="emailform" onSubmit="return checkIt()">
  <hr>
  <div align="center"><center><p><big>Type in your Control Number<strong><input
type="text"
  name="controlNum" size="20"></strong></big></p>
  </center></div><div align="center"><center><p><big><strong>
              
(do
  not </strong>press enter!<strong>)</strong></big></p>
  </center></div><div align="center"><center><p><big>Good Luck!</big></p>
```

```
</center></div><div align="center"><center><p><img src="alum.gif" width="720"
height="15"
 alt="alum.gif (736 bytes)"></p>
 </center></div><div align="center"><center><p><big><big>HIDDEN FIGURES
TEST (PART 1)</big></big></p>
 </center></div><p>    This is a test of your ability to tell which one
of  five simple figures can be found in a more complex pattern.  At the top of each
page  in this test are five simple figures lettered A, B, C, D and E.  Beneath each
row of  figures is a page of patterns.   Each pattern has a row of buttons beneath
it.   Indicate your answer by selecting the letter of the figure which you find in the
pattern.</p>
 <p><u>NOTE</u>: There is only one of these figures in each pattern, and this figure
will
 always be right side up and exactly the same size as one of the five lettered figures.</p>
 <div align="center"><center><p><img src="cf.gif" width="490" height="88"
 alt="cf.gif (31972 bytes)"></p>
 </center></div><p><u>Examples:</u></p>
 <div align="center"><center><p><img src="../images/images_gif/cfex1.gif"
width="356"
 height="87" alt="cfex1.gif (24577 bytes)"></p>
 </center></div><div align="center"><center><p>The figures below show how the
figures are  included in the problems.  Figure A is in the first problem </p>
 </center></div><div align="center"><center><p>and figure D is in the second.</p>
 </center></div><div align="center"><center><p><img
src="../images/images_gif/cf2.gif"
 width="356" height="85" alt="cf2.gif (23590 bytes)"></p>
 </center></div><div align="center"><center><p> </p>
 </center></div><div align="center"><center><table border="0" width="100%">
  <tr>
    <td width="40%" align="center"><strong>I</strong>.  <input type="radio"
    value="cf_1_ex1_A" name="Rex" checked>A   <input type="radio"
value="cf_1_ex1_B"
    name="Rex">B   <input type="radio" value="cf_1_ex1_C"
name="Rex">C<p>   
    <input type="radio" value="cf_1_ex1_D" name="Rex">D   <input
type="radio"
    value="cf_1_ex1_E" name="Rex">E</td>
    <td width="60%" align="center"><strong>II</strong>.  <input type="radio"
    value="cf_1_ex2_A" name="Rex2">A   <input type="radio"
value="cf_1_ex2_B"
    name="Rex2">B   <input type="radio" value="cf_1_ex2_C"
name="Rex2">C<p>     
    <input type="radio" value="cf_1_ex2_D" name="Rex2" checked>D  
<input
    type="radio" value="cf_1_ex2_E" name="Rex2">E</td>
  </tr>
 </table>
```

```
</center></div><div align="center"><center><p>Your score on this test will be the
number  marked correctly minus a fraction of the number marked incorrectly. 
Therefore, it  will <u>not</u> be to your advantage to guess unless you are able to
eliminate one or more  of the answer choices a wrong.  You will have 12 minutes
for this test.  When  you have finished STOP.  Please do no go on to the
remainder of the test until you  are asked to do so.</p>
  </center></div><div align="center"><center><p> </p>
  </center></div><hr>
  <div align="center"><center><p><big><big><u><strong>Part
1</strong></u></big></big></p>
  </center></div><div align="center"><center><p><img src="cf.gif" width="490"
height="88"
  alt="cf.gif (31972 bytes)"></p>
  </center></div><div align="center"><center><p><img
src="../images/images_gif/cf4.gif"
  width="543" height="123" alt="cf4.gif (52192 bytes)"></p>
  </center></div><div align="center"><center><table border="0" width="100%">
    <tr>
      <td width="33%" align="center"><font size="1">  </font><font
size="2"> <strong>1</strong></font><font
      size="1">.  <input type="radio" value="A" name="cf_1_1">A  <input
type="radio"
      value="B" name="cf_1_1">B  <input type="radio" value="C"
name="cf_1_1">C</font><p><font
      size="1">        <input type="radio"
value="D"
      name="cf_1_1">D   <input type="radio" value="E"
name="cf_1_1">E</font></td>
      <td width="33%" align="center"><font size="1"> </font><font size="2">
<strong>2</strong></font><font
      size="1">. <input type="radio" value="A" name="cf_1_2">A    <input
type="radio"
      value="B" name="cf_1_2">B   <input type="radio" value="C"
name="cf_1_2">C</font><p><font
      size="1">      <input type="radio" value="D"
name="cf_1_2">D
         <input type="radio" value="E" name="cf_1_2">E</font></td>
      <td width="34%" align="center"><font size="1"> </font><strong><font
size="2"> 3</font></strong><font
      size="1">. <input type="radio" value="A" name="cf_1_3">A    <input
type="radio"
      value="B" name="cf_1_3">B   <input type="radio" value="C"
name="cf_1_3">C</font><p><font
      size="1">      <input type="radio" value="D"
name="cf_1_3">D
         <input type="radio" value="E" name="cf_1_3">E</font></td>
    </tr>
```

```
 </table>
 </center></div><div align="center"><center><p><img
src="../images/images_gif/cf5.gif"
 width="557" height="124" alt="cf5.gif (55338 bytes)"></p>
 </center></div><div align="center"><center><table border="0" width="100%">
  <tr>
   <td width="33%"><div align="center"><center><p><font
size="1">  </font><font
   size="2"> <strong>4</strong></font><font size="1">.  <input type="radio"
value="A"
   name="cf_1_4">A  <input type="radio" value="B" name="cf_1_4">B 
<input
   type="radio" value="C" name="cf_1_4">C</font></p>
   </center></div><div align="center"><center><p><font
size="1">       
   <input type="radio" value="D" name="cf_1_4">D   <input type="radio"
value="E"
   name="cf_1_4">E</font></td>
   <td width="33%" align="center"><div align="center"><center><p><font
size="1"> </font><font
   size="2"> <strong>5</strong></font><font size="1">. <input type="radio"
value="A"
   name="cf_1_5">A    <input type="radio" value="B"
name="cf_1_5">B   <input
   type="radio" value="C" name="cf_1_5">C</font></p>
   </center></div><div align="center"><center><p><font
size="1">     
   <input type="radio" value="D" name="cf_1_5">D    <input
type="radio" value="E"
   name="cf_1_5">E</font></td>
   <td width="34%" align="center"><div align="center"><center><p><font
size="1"> </font><strong><font
   size="2"> 6</font></strong><font size="1">. <input type="radio" value="A"
name="cf_1_6">A
      <input type="radio" value="B" name="cf_1_6">B  
<input type="radio"
   value="C" name="cf_1_6">C</font></p>
   </center></div><div align="center"><center><p><font
size="1">     
   <input type="radio" value="D" name="cf_1_6">D    <input
type="radio" value="E"
   name="cf_1_6">E</font></td>
  </tr>
 </table>
 </center></div><div align="center"><center><p><img src="cf.gif" width="490"
height="88"
 alt="cf.gif (31972 bytes)"></p>
```

```
  </center></div><div align="center"><center><p><img
src="../images/images_gif/cf6.gif"
  width="538" height="123" alt="cf6.gif (53399 bytes)"></p>
  </center></div><div align="center"><center><table border="0" width="100%">
    <tr>
      <td width="33%"><div align="center"><center><p><font
size="1">  </font><font
      size="2"> <strong>7</strong></font><font size="1">.  <input type="radio"
value="A"
      name="cf_1_7">A  <input type="radio" value="B" name="cf_1_7">B 
<input
      type="radio" value="C" name="cf_1_7">C</font></p>
      </center></div><div align="center"><center><p><font
size="1">       
      <input type="radio" value="D" name="cf_1_7">D   <input type="radio"
value="E"
      name="cf_1_7">E</font></td>
      <td width="33%" align="center"><div align="center"><center><p><font
size="1"> </font><font
      size="2"> <strong>8</strong></font><font size="1">. <input type="radio"
value="A"
      name="cf_1_8">A    <input type="radio" value="B"
name="cf_1_8">B   <input
      type="radio" value="C" name="cf_1_8">C</font></p>
      </center></div><div align="center"><center><p><font
size="1">     
      <input type="radio" value="D" name="cf_1_8">D    <input
type="radio" value="E"
      name="cf_1_8">E</font></td>
      <td width="34%" align="center"><div align="center"><center><p><font
size="1"> </font><strong><font
      size="2"> 9</font></strong><font size="1">. <input type="radio" value="A"
name="cf_1_9">A
         <input type="radio" value="B" name="cf_1_9">B  
<input type="radio"
      value="C" name="cf_1_9">C</font></p>
      </center></div><div align="center"><center><p><font
size="1">     
      <input type="radio" value="D" name="cf_1_9">D    <input
type="radio" value="E"
      name="cf_1_9">E</font></td>
    </tr>
  </table>
  </center></div><div align="center"><center><p><img
src="../images/images_gif/cf7.gif"
  width="568" height="129" alt="cf7.gif (57900 bytes)"></p>
  </center></div><div align="center"><center><table border="0" width="100%">
```

```
  <tr>
    <td width="33%"><div align="center"><center><p><font
size="1">  </font><font
    size="2"> <strong>10</strong></font><font size="1">.  <input type="radio"
value="A"
    name="cf_1_10">A  <input type="radio" value="B"
name="cf_1_10">B  <input
    type="radio" value="C" name="cf_1_10">C</font></p>
    </center></div><div align="center"><center><p><font
size="1">       
    <input type="radio" value="D" name="cf_1_10">D   <input type="radio"
value="E"
    name="cf_1_10">E</font></td>
    <td width="33%" align="center"><div align="center"><center><p><font
size="1"> </font><font
    size="2"> <strong>11</strong></font><font size="1">. <input type="radio"
value="A"
    name="cf_1_11">A    <input type="radio" value="B"
name="cf_1_11">B   <input
    type="radio" value="C" name="cf_1_11">C</font></p>
    </center></div><div align="center"><center><p><font
size="1">     
    <input type="radio" value="D" name="cf_1_11">D    <input
type="radio" value="E"
    name="cf_1_11">E</font></td>
    <td width="34%" align="center"><div align="center"><center><p><font
size="1"> </font><strong><font
    size="2"> 12</font></strong><font size="1">. <input type="radio" value="A"
name="cf_1_12">A
       <input type="radio" value="B" name="cf_1_12">B  
<input
    type="radio" value="C" name="cf_1_12">C</font></p>
    </center></div><div align="center"><center><p><font
size="1">     
    <input type="radio" value="D" name="cf_1_12">D    <input
type="radio" value="E"
    name="cf_1_12">E</font></td>
  </tr>
 </table>
 </center></div><div align="center"><center><p><img src="cf.gif" width="490"
height="88"
 alt="cf.gif (31972 bytes)"></p>
 </center></div><div align="center"><center><p><img
src="../images/images_gif/cf8.gif"
 width="399" height="125" alt="cf8.gif (38323 bytes)"></p>
 </center></div><div align="center"><center><table border="0" width="100%">
  <tr>
```

```
    <td width="33%"><div align="center"><center><p><font
size="1">  </font><font
    size="2"> <strong>13</strong></font><font size="1">.  <input type="radio"
value="A"
    name="cf_1_13">A  <input type="radio" value="B"
name="cf_1_13">B  <input
    type="radio" value="C" name="cf_1_13">C</font></p>
    </center></div><div align="center"><center><p><font
size="1">       
    <input type="radio" value="D" name="cf_1_13">D   <input type="radio"
value="E"
    name="cf_1_13">E</font></td>
    <td width="33%" align="center"><div align="center"><center><p><font
size="1"> </font><font
    size="2"> <strong>14</strong></font><font size="1">. <input type="radio"
value="A"
    name="cf_1_14">A    <input type="radio" value="B"
name="cf_1_14">B   <input
    type="radio" value="C" name="cf_1_14">C</font></p>
    </center></div><div align="center"><center><p><font
size="1">     
    <input type="radio" value="D" name="cf_1_14">D    <input
type="radio" value="E"
    name="cf_1_14">E</font></td>
   </tr>
  </table>
  </center></div><div align="center"><center><p><img
src="../images/images_gif/cf9.gif"
  width="418" height="126" alt="cf9.gif (40205 bytes)"></p>
  </center></div><div align="center"><center><table border="0" width="100%">
   <tr>
    <td width="33%" align="center"><div align="center"><center><p><font
size="1">  </font><font
    size="2"> <strong>15</strong></font><font size="1">.  <input type="radio"
value="A"
    name="cf_1_15">A  <input type="radio" value="B"
name="cf_1_15">B  <input
    type="radio" value="C" name="cf_1_15">C</font></p>
    </center></div><div align="center"><center><p><font
size="1">       
    <input type="radio" value="D" name="cf_1_15">D   <input type="radio"
value="E"
    name="cf_1_15">E</font></td>
    <td width="33%" align="center"><div align="center"><center><p><font
size="1"> </font><font
    size="2"> <strong>16</strong></font><font size="1">. <input type="radio"
value="A"
```

```
    name="cf_1_16">A    <input type="radio" value="B"
name="cf_1_16">B   <input
    type="radio" value="C" name="cf_1_16">C</font></p>
    </center></div><div align="center"><center><p><font
size="1">     
    <input type="radio" value="D" name="cf_1_16">D    <input
type="radio" value="E"
    name="cf_1_16">E</font></td>
   </tr>
  </table>
  </center></div><div align="center"><center><p><u>STOP</u>! Do not scroll down
further
  until asked to do so <u>STOP</u>!</p>
  </center></div><hr align="center">
  <div align="center"><center><p><img src="alum.gif" width="720" height="15"
  alt="alum.gif (736 bytes)"></p>
  </center></div><div align="center"><center><p> </p>
  </center></div><div align="center"><center><p><big><big>LETTER SETS TEST
(Part 2)</big></big></p>
  </center></div><div align="center"><center><p>    Each problem
in this test  has five sets of letters with four letters in each set.  Four of the sets of
letters  are alike in some way.   You are to find the rule that makes these four
alike.   The fifth letter set is different from them and will not fit this rule. 
Select the  set of letters that is different.</p>
  </center></div><div align="center"><center><p><u>NOTE</u>:  The rules will
<u>not</u>  be based on the sounds of sets of letters, the shapes of letters, or whether
letter  combinations form words or parts of words.</p>
  </center></div><div align="center"><center><p><u>Examples:</u></p>
  </center></div><div align="center"><center><table border="0" width="100%">
   <tr>
    <td width="14%">A</td>
    <td width="5%">NOPQ</td>
    <td width="9%"><input type="radio" name="I_ex_A" value="NOPQ"></td>
    <td width="4%">DEFL</td>
    <td width="10%"><input type="radio" name="I_ex_A" value="DEFL"
checked></td>
    <td width="5%">ABCD</td>
    <td width="9%"><input type="radio" name="I_ex_A" value="ABCD"></td>
    <td width="4%">HIJK</td>
    <td width="11%"><input type="radio" name="I_ex_A" value=" HIJK"></td>
    <td width="5%">UVWX</td>
    <td width="10%"><input type="radio" name="I_ex_A" value="UVWX"></td>
   </tr>
   <tr>
    <td width="14%">B</td>
    <td width="5%">NLIK</td>
    <td width="9%"><input type="radio" name="I_ex_B" value="NLIK"></td>
```

```
    <td width="4%">PLIK</td>
    <td width="10%"><input type="radio" name="I_ex_B" value="PLIK"></td>
    <td width="5%">QLIK</td>
    <td width="9%"><input type="radio" name="I_ex_B" value="QLIK"></td>
    <td width="4%">THIK</td>
    <td width="11%"><input type="radio" name="I_ex_B" value="THIK"
checked></td>
    <td width="5%">VLIK</td>
    <td width="10%"><input type="radio" name="I_ex_B" value="VLIK"></td>
  </tr>
 </table>
 </center></div><div align="center"><center><p>     In
Example A, four
 of the sets have letters in alphabetical order.  The button next to set DEFL has
been  selected.  In Example B, four of the sets contain the letter L. 
Therefore, the  button next to THIK has been
 selected.          </p>
 </center></div><div align="center"><center><p>Your score on this test will be the
number  marked correctly minus a fraction of the number marked incorrectly. 
Therefore, it  will <u>not</u> be to your advantage to guess unless you are able to
eliminate one or more  of the answer choices a wrong.   You will have 12 minutes
for this test.  When  you have finished, Press the &quot;Submit Answers &quot;
button.  </p>
 </center></div><hr align="center">
 <div align="center"><center><p><big><big><u><strong>Part
2</strong></u></big></big></p>
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    <td width="9%"><font face="Courier"><input type="radio" name="I_1"
value="QPPQ"></font></td>
    <td width="4%"><font face="Courier">HGHH</font></td>
    <td width="10%"><font face="Courier"><input type="radio" name="I_1"
value="HGHH"></font></td>
    <td width="5%"><font face="Courier">TTTU</font></td>
    <td width="9%"><font face="Courier"><input type="radio" name="I_1"
value="TTTU"></font></td>
    <td width="4%"><font face="Courier">DDDE</font></td>
    <td width="11%"><font face="Courier"><input type="radio" name="I_1"
value="DDDE"></font></td>
    <td width="5%"><font face="Courier">MLMM</font></td>
    <td width="10%"><font face="Courier"><input type="radio" name="I_1"
value="MLMM"></font></td>
  </tr>
```

```
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value="BCDE"></font></td>
    <td width="4%"><font face="Courier">FGHI</font></td>
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value="FGHI"></font></td>
    <td width="5%"><font face="Courier">JKLM</font></td>
    <td width="9%"><font face="Courier"><input type="radio" name="I_2"
value="JKLM"></font></td>
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    <td width="11%"><font face="Courier"><input type="radio" name="I_2"
value="PRST"></font></td>
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    <td width="9%"><font face="Courier"><input type="radio" name="I_3"
value="BVZC"></font></td>
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    <td width="10%"><font face="Courier"><input type="radio" name="I_3"
value="FVZG"></font></td>
    <td width="5%"><font face="Courier">JVZK</font></td>
    <td width="9%"><font face="Courier"><input type="radio" name="I_3"
value="JVZK"></font></td>
    <td width="4%"><font face="Courier">PWXQ</font></td>
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value="PWXQ"></font></td>
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```

```
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value="BCEF"></font></td>
    <td width="4%"><font face="Courier">FGIJ</font></td>
    <td width="10%"><font face="Courier"><input type="radio" name="I_4"
value="FGIJ"></font></td>
    <td width="5%"><font face="Courier">STWX</font></td>
    <td width="9%"><font face="Courier"><input type="radio" name="I_4"
value="STWX"></font></td>
    <td width="4%"><font face="Courier">CDFG</font></td>
    <td width="11%"><font face="Courier"><input type="radio" name="I_4"
value="CDFG"></font></td>
    <td width="5%"><font face="Courier">PQST</font></td>
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value="PQST"></font></td>
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    <td width="4%"><font face="Courier">GFFG</font></td>
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value="GFFG"></font></td>
    <td width="5%"><font face="Courier">LMML</font></td>
    <td width="9%"><font face="Courier"><input type="radio" name="I_5"
value="LMML"></font></td>
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value="AAPP"></font></td>
    <td width="4%"><font face="Courier">CCRR</font></td>
```

```
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value="EETT"></font></td>
    <td width="5%"><font face="Courier">DDSS</font></td>
    <td width="10%"><font face="Courier"><input type="radio" name="I_6"
value="DDSS"></font></td>
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value="ABDC"></font></td>
    <td width="4%"><font face="Courier">EGFH</font></td>
    <td width="10%"><font face="Courier"><input type="radio" name="I_7"
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value="IJKL"></font></td>
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    <td width="11%"><font face="Courier"><input type="radio" name="I_7" value="
OPRQ"></font></td>
    <td width="5%"><font face="Courier">UVXW</font></td>
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value="UVXW"></font></td>
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value="CERT"></font></td>
    <td width="4%"><font face="Courier">KMTV</font></td>
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value="KMTV"></font></td>
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```

```
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    <td width="5%"><font face="Courier">HJPR</font></td>
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    <td width="9%"><font face="Courier"><input type="radio" name="I_9"
value="VIJW"></font></td>
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COPD"></font></td>
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```

```
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    <td width="5%"><font face="Courier">ZIFX</font></td>
    <td width="9%"><font face="Courier"><input type="radio" name="I_13"
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    <td width="4%"><font face="Courier">KXVH</font></td>
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    <td width="5%"><font face="Courier">MZXJ</font></td>
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```

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value="DFIM"></font></td>
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value="LHEC"></font></td>
   </tr>
  </table>
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BACK TO PART
  1.  <u>STOP!</u></p>
  </center></div><div align="center"><center><p>Please press the SUBMIT
ANSWERS button.</p>
  </center></div><div align="center"><center><table border="0" width="100%">
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    <td width="100%" align="center"><div align="center"><center><p><input
type="submit"
    value="Submit Answers" name="Submit Button"></td>
   </tr>
   <tr align="center">
    <td width="100%"><div align="center"><center><p><strong><big>Thank you for
your time.</big></strong></p>
    </center></div>

  <p> Copyright &copy 1962, 1975 by Educational Testing Service.  All rights reserved.
Reproduced under license.</p>
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</form>

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# APPENDIX B. SUPPORT DOCUMENTS AND FORMS

This appendix contains the forms and documents that were required for tracking, briefing and evaluating the subjects. The following forms are included: Brief Sheet, Consent Form, Pre-Evaluation Questionnaire and Post-Evaluation Questionnaire.

## BRIEF SHEET

1. The experiment you are about to participate in is very simple in nature. You will start out by answering a short questionnaire and filling out a consent form. After the paperwork is out of the way and your questions are answered, you will asked to relax for approximately 10 minutes prior to beginning the online evaluation.

2. During the relaxation period you will asked to put on headphones and then arrange yourself comfortably in a chair. You will then press the "ON" button on the device, put on a pair of darkened glasses and relax. During this period you may either keep your eyes open or closed. Please try to remain as quiet as possible during this period.

3. An assistant will notify you when the 10 minutes is up. You will then take off the darkened glasses and headphones and will proceed to the computer lab. You will take your assigned seat in front of a computer and monitor. For the purpose of this experiment please sit so that your eyes are within 18" of the monitor. Do not adjust the size of the application windows. Use the horizontal and vertical scroll bars to bring objects into the window.

4. Once seated type your Control Number into the space provided. The assistant will give you a few minutes to read the directions and then will announce how much time you have to complete the evaluation. Please follow the assistant's directions. If you have questions or problems that cannot be answered by the online directions, ask the assistant. Although we ask that you do not close any processes, if you feel that you must close one, you may. Once you have completed the evaluation, simply press the "Submit" button. If you have not yet entered your Control Number you will prompted to do so. At this time you are free to exit the lab

5. You will be sent a questionnaire via e-mail within 24 hours. Please take the time to fill out and respond to this last portion of the testing process.

6. Once again, this experiment is voluntary and it is not expected that any ill effects will be induced. Remember if you are an epileptic or are photosensitive, you must not participate in this study. If you have any questions please ask them now.

## CONSENT FORM

### *Human Computer Interaction Experiment*

**Contact Information**: This study is being conducted by Major Robert Peterman (CS73, 656-2509, peterman@cs.nps.navy.mil).

**Risks of being in the study**: If you are an epileptic or are photosensitive, you should not participate in this study. Research indicates that adults are not susceptible to seizures triggered by photo stimulation. Also, the photo stimulation that you might be exposed to is not in the triggering frequency range. This study has no other unordinary risks beyond those encountered in your everyday workplace.

**Confidentiality**: The records of this study will be kept private. We will not make any information publicly accessible that might make it possible to identify you as a participant.

**Voluntary nature of the study**: If you decide to participate, you are free to withdraw at any time without prejudice.

**If desired, you will be given a copy of this form for your records.**

**Statement of consent**: I have read the above information. I have asked questions and have had my questions answered. I consent to participate in the study.

__________________________________________________________

Signature Date

__________________________________________________________

Signature of Investigator Date

**Pre-Evaluation Questionnaire**

| **Control Number** | |
|---|---|

Please answer the following question using 1 as low or poor, 3 as average, and 5 as high or very good.

| | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| How would you describe your overall computer abilities? | | | | | |
| How proficient are you with navigating a web page? | | | | | |
| How proficient are you with a keyboard and mouse? | | | | | |
| How proficient are you in reading and comprehending the English language? | | | | | |
| How would you rate yourself in terms of intelligence? | | | | | |
| How creative are you? | | | | | |
| How would you rate your overall cognitive abilities? | | | | | |
| How would you describe your present mood? | | | | | |
| How would you describe your current state of mind?<br>1 = Tired, slow thinking 5 = Alert, fast thinking | | | | | |
| How would you describe your current physical state?<br>1 = Tired 5 = Alert | | | | | |
| | | | | | |

**Post Evaluation Questionnaire**

| **Control Number** | |
|---|---|

Please answer the following question using 1 as low or poor, 3 as average, and 5 as high or very good.

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. Did the relaxation period have any effect on your state of mind?<br>1 = No 5 = Yes | | | | | |
| 2. After finishing the relaxation period, how would you describe your state of mind?<br>1 = Tired, slow thinking 5 = Alert, fast thinking | | | | | |
| 3. Did the relaxation period have any effect on your physical state?<br>1 = No 5 = Yes (If yes please describe in space below) | | | | | |
| 4. After finishing the relaxation period, how would you describe your physical state?<br>1 = Tired 5 = Alert | | | | | |
| 5. Did the online evaluation portion have any effect on your state of mind?<br>1 = No 5 = Yes | | | | | |
| 6. After finishing the online evaluation, how would you describe your state of mind?<br>1 = Tired, slow thinking 5 = Alert, fast thinking | | | | | |
| 7. Did the online evaluation portion have any effect on your physical state?<br>1 = No 5 = Yes (If yes please describe in space below) | | | | | |
| 8. After finishing the online evaluation, how would you describe your physical state?<br>1 = Tired 5 = Alert | | | | | |
| 9. Did you experience any effects 3-24 hours after taking part in the experiment?<br>1 = No 5 = Yes (If yes please describe in space below) | | | | | |

NOTES:

# APPENDIX C. RESULTS OF PILOT STUDY

This appendix contains the complete set of results from this pilot study. They are arranged in the following order: relaxation period observations, Pre-Evaluation Questionnaire results, cognitive evaluation period observations, cognitive evaluation scores, and Post-evaluation Questionnaire results.

## Relaxation Period Observations

| Control # | Subject Quiet? | Subject Still? | Subject Relaxed? | Notes |
|---|---|---|---|---|
| 10 | T | T | F | Quiet, Tapping foot |
| 11 | T | T | T | No movement |
| 12 | T | F | T | Little movement |
| 13 | T | F | T | Small movement |
| 15 | F | F | F | Tense, movement |
| 17 | T | T | T | Still |
| 18 | F | F | F | Very Tense |
| **Average** | **5-T 2-F** | **3-T 4-F** | **4-T 3-F** | |
| **Pct. True** | 72% | **42%** | **57%** | Movers, tense |
| | | | | |
| 20 | T | T | T | Asleep |
| 21 | T | T | T | Small movements |
| 22 | T | F | T | Quiet, moving |
| 23 | T | T | T | Quiet |
| 24 | T | T | T | Very still, asleep? |
| 25 | F | F | T | Moderate movement |
| 26 | F | F | F | Bored look |
| 27 | T | T | T | Quiet |
| 28 | T | T | T | Very relaxed, feet up |
| 29 | T | T | T | Quiet |
| **Average** | **8-T 2-F** | **7-T 3-F** | **9-T 1-F** | |
| **Pct. True** | **80%** | **70%** | **90%** | Relaxed |
| | | | | |
| 30 | F | F | F | Tense, not relaxed |
| 31 | T | T | T | Quiet, Asleep? |
| 32 | T | T | T | Very still |
| 33 | T | T | T | Quiet |
| 35 | T | T | F | Held head in hands |
| 36 | T | T | T | Quiet, still |
| 37 | T | T | T | Relaxed, feet up |
| 38 | T | T | T | Still, upright |
| **Average** | **7-T 1-F** | **7-T 1-F** | **6-T 2-F** | |
| **Pct. True** | **88%** | **88%** | **75%** | Relaxed |

## Pre-Evaluation Questionnaire Results

| Control # | Computer Abilities | Webpage Navigation abilities | Keyboard/Mouse Abilities |
|---|---|---|---|
| 10 | 5 | 5 | 5 |
| 11 | 5 | 5 | 5 |
| 12 | 3 | 4 | 4 |
| 13 | 4 | 4 | 4 |
| 15 | 5 | 4 | 4 |
| 17 | 4 | 5 | 5 |
| 18 | 2 | 3 | 2 |
| **Average** | **4** | **4.29** | **4.14** |
| **StdDev** | **1.16** | **0.76** | **1.07** |
| | | | |
| 20 | 5 | 5 | 5 |
| 21 | 4 | 4 | 5 |
| 22 | 5 | 5 | 5 |
| 23 | 5 | 5 | 5 |
| 24 | 3 | 4 | 4 |
| 25 | 4 | 4 | 4 |
| 26 | 4 | 5 | 4 |
| 27 | 3 | 3 | 4 |
| 28 | 4 | 5 | 5 |
| 29 | 5 | 5 | 5 |
| **Average** | **4.2** | **4.5** | **4.6** |
| **StdDev** | **0.79** | **0.71** | **0.52** |
| | | | |
| 30 | 5 | 5 | 4 |
| 31 | 3 | 3 | 4 |
| 32 | 5 | 5 | 5 |
| 33 | 3 | 4 | 4 |
| 35 | 3 | 3 | 3 |
| 36 | 5 | 5 | 5 |
| 37 | 3 | 3 | 5 |
| 38 | 4 | 5 | 5 |
| **Average** | **3.88** | **4.13** | **4.38** |
| **StdDev** | **0.99** | **0.99** | **0.74** |

| Control # | English Proficiency | Intelligence Level | Level of Creativity |
|---|---|---|---|
| 10 | 5 | 5 | 4 |
| 11 | 5 | 4 | 4 |
| 12 | 5 | 3 | 5 |
| 13 | 3 | 3 | 3 |
| 15 | 5 | 3 | 4 |
| 17 | 5 | 4 | 3 |
| 18 | 4 | 4 | 5 |
| **Average** | **4.57** | **3.71** | **4** |
| **StdDev** | **0.79** | **0.76** | **0.82** |
| | | | |
| 20 | 3 | 3 | 3 |
| 21 | 5 | 4 | 3 |
| 22 | 5 | 4 | 4 |
| 23 | 5 | 4 | 4 |
| 24 | 3 | 3 | 4 |
| 25 | 4 | 4 | 4 |
| 26 | 4 | 4 | 4 |
| 27 | 5 | 4 | 3 |
| 28 | 5 | 4 | 4 |
| 29 | 5 | 4 | 3 |
| **Average** | **4.4** | **3.8** | **3.6** |
| **StdDev** | **0.84** | **0.42** | **0.52** |
| | | | |
| 30 | 4 | 4 | 4 |
| 31 | 4 | 4 | 4 |
| 32 | 5 | 4 | 4 |
| 33 | 5 | 3 | 3 |
| 35 | 3 | 3 | 3 |
| 36 | 5 | 4 | 4 |
| 37 | 5 | 3 | 4 |
| 38 | 5 | 3 | 2 |
| **Average** | **4.5** | **3.5** | **3.5** |
| **StdDev** | **0.76** | **0.54** | **0.76** |

| Control # | Cognitive Abilities | Present Mood | Present State of Mind |
|---|---|---|---|
| 10 | 5 | 5 | 5 |
| 11 | 5 | 4 | 3 |
| 12 | 4 | 4 | 4 |
| 13 | 4 | 4 | 4 |
| 15 | 4 | 4 | 4 |
| 17 | 4 | 4 | 5 |
| 18 | 4 | 4 | 3 |
| **Average** | **4.29** | **4.14** | **4** |
| **StdDev** | **0.49** | **0.38** | **0.82** |
| | | | |
| 20 | 4 | 4 | 3 |
| 21 | 3 | 5 | 3 |
| 22 | 4 | 3 | 5 |
| 23 | 4 | 4 | 4 |
| 24 | 3 | 4 | 4 |
| 25 | 3 | 4 | 4 |
| 26 | 4 | 4 | 5 |
| 27 | 4 | 4 | 4 |
| 28 | 4 | 4 | 4 |
| 29 | 4 | 3 | 3 |
| **Average** | **3.7** | **3.9** | **3.9** |
| **StdDev** | **0.48** | **0.57** | **0.74** |
| | | | |
| 30 | 4 | 3 | 3 |
| 31 | 4 | 4 | 3 |
| 32 | 4 | 4 | 4 |
| 33 | 4 | 3 | 3 |
| 35 | 3 | 3 | 3 |
| 36 | 4 | 5 | 4 |
| 37 | 3 | 4 | 2 |
| 38 | 3 | 3 | 2 |
| **Average** | **3.63** | **3.63** | **3** |
| **StdDev** | **0.52** | **0.74** | **0.76** |

| Control # | Present Physical State | Time |
|---|---|---|
| 10 | 5 | PM |
| 11 | 3 | PM |
| 12 | 4 | PM |
| 13 | 4 | AM |
| 15 | 4 | AM |
| 17 | 5 | PM |
| 18 | 4 | PM |
| Average | 4.14 | |
| StdDev | 0.69 | |
| | | |
| 20 | 3 | PM |
| 21 | 3 | PM |
| 22 | 5 | PM |
| 23 | 4 | AM |
| 24 | 4 | AM |
| 25 | 4 | AM |
| 26 | 5 | AM |
| 27 | 4 | PM |
| 28 | 3 | AM |
| 29 | 3 | PM |
| Average | 3.8 | |
| StdDev | 0.79 | |
| | | |
| 30 | 3 | PM |
| 31 | 3 | PM |
| 32 | 3 | PM |
| 33 | 3 | AM |
| 35 | 3 | AM |
| 36 | 5 | AM |
| 37 | 3 | PM |
| 38 | 2 | PM |
| Average | 3.13 | |
| StdDev | 0.84 | |

## Cognitive Evaluation Period Observations

| Control # | Comfortable? | Still? | # Times Moved | # Times rubbed eyes |
|---|---|---|---|---|
| **10** | Lost Data | | | |
| **11** | | | | |
| **12** | | | | |
| **13** | T | T | 1 | 0 |
| **15** | F | F | 2 | 0 |
| **17** | T | T | 4 | 0 |
| **18** | F | F | 5 | 0 |
| **Average** | **2-T 2-F** | **2-T 2-F** | **3** | **0** |
| **Pct. True** | **50%** | **50%** | | |
| **StdDev** | | | **1.83** | **0** |
| | | | | |
| **20** | T | T | 8 | 1 |
| **21** | T | F | 6 | 0 |
| **22** | T | T | 8 | 0 |
| **23** | T | T | 5 | 0 |
| **24** | T | F | 45 | 0 |
| **25** | F | F | 11 | 0 |
| **26** | T | T | 4 | 0 |
| **27** | T | F | 7 | 0 |
| **28** | T | T | 7 | 0 |
| **29** | T | F | 9 | 0 |
| **Average** | **9-T 1-F** | **5-T 5-F** | **11** | **0.1** |
| **Pct. True** | **90%** | **50%** | | |
| **StdDev** | | | **12.11** | **0.32** |
| | | | | |
| **30** | T | F | 6 | 0 |
| **31** | T | T | 1 | 0 |
| **32** | T | T | 11 | 0 |
| **33** | T | F | 17 | 0 |
| **35** | T | F | 16 | 0 |
| **36** | T | F | 11 | 0 |
| **37** | T | F | 13 | 0 |
| **38** | T | F | 9 | 0 |
| **Average** | **8-T** | **2-T 6-F** | **10.5** | **0** |
| **Pct. True** | **100%** | **25%** | | |
| **StdDev** | | | **5.24** | **0** |

| Control # | Comfortable? | Still? | # Times Moved | # Times rubbed eyes |
|---|---|---|---|---|
| 10 | Lost Data | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | T | T | 1 | 0 |
| 15 | F | F | 2 | 0 |
| 17 | T | T | 4 | 0 |
| 18 | F | F | 5 | 0 |
| **Average** | **2-T 2-F** | **2-T 2-F** | **3** | **0** |
| **Pct. True** | **50%** | **50%** | | |
| **StdDev** | | | **1.83** | **0** |
| | | | | |
| 20 | T | T | 8 | 1 |
| 21 | T | F | 6 | 0 |
| 22 | T | T | 8 | 0 |
| 23 | T | T | 5 | 0 |
| 24 | T | F | 45 | 0 |
| 25 | F | F | 11 | 0 |
| 26 | T | T | 4 | 0 |
| 27 | T | F | 7 | 0 |
| 28 | T | T | 7 | 0 |
| 29 | T | F | 9 | 0 |
| **Average** | **9-T 1-F** | **5-T 5-F** | **11** | **0.1** |
| **Pct. True** | **90%** | **50%** | | |
| **StdDev** | | | **12.11** | **0.32** |
| | | | | |
| 30 | T | F | 6 | 0 |
| 31 | T | T | 1 | 0 |
| 32 | T | T | 11 | 0 |
| 33 | T | F | 17 | 0 |
| 35 | T | F | 16 | 0 |
| 36 | T | F | 11 | 0 |
| 37 | T | F | 13 | 0 |
| 38 | T | F | 9 | 0 |
| **Average** | **8-T** | **2-T 6-F** | **10.5** | **0** |
| **Pct. True** | **100%** | **25%** | | |
| **StdDev** | | | **5.24** | **0** |

| Control # | #Times moved head | Constant Distance? | Notes |
|---|---|---|---|
| **10** | Lost Data | | |
| **11** | | | |
| **12** | | | |
| **13** | 11 | T | Small movement, intense |
| **15** | 16 | F | Lots of hand movement |
| **17** | 33 | T | V. concentrating, expressed relief when complete |
| **18** | 35 | T | Eyebrow movement |
| **Average** | **23.75** | **3-T 1-F** | |
| **Pct.True** | | **75%** | **50% each way, stayed close to screen** |
| **StdDev** | **12.04** | | |
| | | | |
| **20** | 29 | T | Drank water, sat with eyes closed, looked around |
| **21** | 14 | F | Looked around, lots of blinking |
| **22** | 18 | F | Very still |
| **23** | 13 | T | Kept looking at screen after "time-up" |
| **24** | 30 | F | |
| **25** | 44 | F | Moved away as time went on |
| **26** | 35 | T | Lots of hand movement |
| **27** | 83 | F | Talked to self/ lips moving |
| **28** | 15 | F | Moved away slowly |
| **29** | 107 | F | Lots of head/hand movement |
| **Average** | **38.8** | **3-T 7-F** | |
| **Pct.True** | | **30%** | **Lots of movement of head, body, moved away** |
| **StdDev** | **31.80** | | |
| | | | |
| **30** | 58 | F | Moved away |
| **31** | 47 | T | Appeared relaxed |
| **32** | 32 | T | Very still, concentrating |
| **33** | 22 | F | |
| **35** | 11 | T | Not relaxed looking (sat in wrong spot to start) |
| **36** | 38 | F | |
| **37** | 29 | T | Maintained distance from screen |
| **38** | 34 | F | Slowly moved away |
| **Average** | **33.88** | **4-T 4-F** | |
| **Pct.True** | | **50%** | **Good amount of both head and body movement** |
| **StdDev** | **14.46** | | |

## Test Scores on Cognitive Evaluation

| Control # | Part 1 Answered | Part 1 Correct | Part 2 Answered | Part 2 Correct |
|---|---|---|---|---|
| 10 | 5 | 5 | 14 | 11 |
| 11 | 5 | 5 | 14 | 12 |
| 12 | 16 | 3 | 15 | 12 |
| 13 | 16 | 7 | 13 | 9 |
| 15 | 5 | 1 | 13 | 10 |
| 17 | 3 | 3 | 14 | 13 |
| 18 | 9 | 6 | 15 | 15 |
| **Average** | **8.43** | **4.29** | **14** | **11.71** |
| **StdDev** | **5.47** | **2.06** | **0.82** | **1.98** |
| **# cases** | **7** | **7** | **7** | **7** |
| **Sum** | **59** | **30** | **98** | **82** |
| | | | | |
| 20 | 3 | 1 | 15 | 12 |
| 21 | 16 | 6 | 15 | 14 |
| 22 | 3 | 1 | 15 | 13 |
| 23 | 9 | 9 | 15 | 12 |
| 24 | 5 | 4 | 15 | 14 |
| 25 | 6 | 3 | 11 | 8 |
| 26 | 9 | 5 | 8 | 5 |
| 27 | 5 | 5 | 14 | 13 |
| 28 | 16 | 6 | 15 | 12 |
| 29 | 11 | 11 | 14 | 11 |
| **Average** | **8.3** | **5.1** | **13.7** | **11.4** |
| **StdDev** | **4.83** | **3.19** | **2.36** | **2.84** |
| **# cases** | **10** | **10** | **10** | **10** |
| **Sum** | **83** | **51** | **137** | **114** |
| | | | | |
| 30 | 11 | 11 | 15 | 12 |
| 31 | 2 | 2 | 15 | 15 |
| 32 | 8 | 2 | 15 | 11 |
| 33 | 7 | 3 | 14 | 14 |
| 35 | 3 | 0 | 14 | 12 |
| 36 | 16 | 7 | 14 | 11 |
| 37 | 2 | 2 | 14 | 14 |
| 38 | 7 | 7 | 12 | 11 |
| **Average** | **7** | **4.25** | **14.125** | **12.5** |
| **StdDev** | **4.84** | **3.69** | **0.99** | **1.60** |
| **# cases** | **8** | **8** | **8** | **8** |
| **Sum** | **56** | **34** | **113** | **100** |

## Post-evaluation Questionnaire results

| Control # | 1) Relax Period Effects on State of Mind? | 2) Post-Relax Period State of Mind |
|---|---|---|
| 10 | T | 3 |
| 11 | T | 3 |
| 12 | T | 1 |
| 13 | T | 4 |
| 15 | F | 4 |
| 17 | T | 3 |
| 18 | F | 3 |
| **Avg.** | **5-T 2-F** | **3** |
| **Pct. True** | **71%** | |
| **StdDev** | | **1** |
| | | |
| 20 | T | 4 |
| 21 | T | 3 |
| 22 | F | 2 |
| 23 | T | 4 |
| 24 | T/F | 4 |
| 25 | T | 4 |
| 26 | F | 1 |
| 27 | T | 4 |
| 28 | T | 1 |
| 29 | T | 3 |
| **Avg.** | **7-T 2-F 1-T/F** | **3** |
| **Pct. True** | **70%** | |
| **StdDev** | | **1.25** |
| | | |
| 30 | T | 4 |
| 31 | T | 3 |
| 32 | T | 4 |
| 33 | T | 3 |
| 35 | T | 1 |
| 36 | T | 4 |
| 37 | F | 2 |
| 38 | T | 3 |
| **Avg.** | **7-T 1-F** | **3** |
| **Pct. True** | **88%** | |
| **StdDev** | | **1.07** |

| Control # | 3) Relax Period Effects on Physical State? | 4) Post-Relax Period Physical State |
|---|---|---|
| 10 | T | 3 |
| 11 | T | 4 |
| 12 | T | 1 |
| 13 | T | 5 |
| 15 | F | 4 |
| 17 | T | 3 |
| 18 | F | 3 |
| **Average** | **5-T 2-F** | **3.29** |
| **Pct. True** | **71%** | |
| **StdDev** | | **1.25** |
| | | |
| 20 | T | 4 |
| 21 | T/F | 3 |
| 22 | F | 3 |
| 23 | T | 4 |
| 24 | T/F | 4 |
| 25 | T | 4 |
| 26 | T/F | 2 |
| 27 | F | 4 |
| 28 | T | 1 |
| 29 | T | 3 |
| **Average** | **5-T 2-F 3-T/F** | **3.2** |
| **Pct. True** | **50%** | |
| **StdDev** | | **1.03** |
| | | |
| | | |
| 30 | T/F | 3 |
| 31 | T/F | 3 |
| 32 | T/F | 4 |
| 33 | T/F | 4 |
| 35 | F | 1 |
| 36 | T/F | 1 |
| 37 | F | 3 |
| 38 | T/F | 3 |
| **Average** | **6-T/F 2-F** | **2.75** |
| **Pct. True** | **75%** | |
| **StdDev** | | **1.17** |

| Control # | 5) Evaluation Period effects on State of Mind? | 6) Post Evaluation Period State of Mind |
|---|---|---|
| 10 | T | 2 |
| 11 | T | 4 |
| 12 | T | 5 |
| 13 | T | 4 |
| 15 | T | 2 |
| 17 | T | 4 |
| 18 | T | 2 |
| **Average** | **7-T** | **3.29** |
| **Pct. True** | **100%** | |
| **StdDev** | | **1.25** |
| | | |
| 20 | T | 3 |
| 21 | F | 0 |
| 22 | F | 4 |
| 23 | T | 4 |
| 24 | F | 4 |
| 25 | F | 4 |
| 26 | T/F | 2 |
| 27 | T | 5 |
| 28 | T | 1 |
| 29 | T | 3 |
| **Average** | **5-T 4-F 1-T/F** | **3** |
| **Pct. True** | **50%** | |
| **StdDev** | | **1.56** |
| | | |
| | | |
| 30 | T/F | 3 |
| 31 | T/F | 2 |
| 32 | T/F | 3 |
| 33 | T/F | 4 |
| 35 | T/F | 5 |
| 36 | F | 1 |
| 37 | T/F | 2 |
| 38 | T/F | 4 |
| **Average** | **7-T/F 1-F** | **3** |
| **Pct. True** | **88%** | |
| **StdDev** | | **1.31** |

| Control # | 7) Evaluation Period Effects on Physical State? | 8) Post-Evaluation Period Physical State | 9) Effects in 3-24hrs after participation? |
|---|---|---|---|
| 10 | F | 3 | T |
| 11 | T | 4 | F |
| 12 | F | 5 | T |
| 13 | T | 4 | F |
| 15 | F | 4 | F |
| 17 | T | 3 | F |
| 18 | T | 2 | F |
| **Average** | **4-T 3-F** | **3.57** | **2-T 5-F** |
| **Pct. True** | **57%** | | **29%** |
| **StdDev** | | **0.98** | |
| | | | |
| 20 | T | 4 | F |
| 21 | T/F | 2 | F |
| 22 | F | 3 | F |
| 23 | F | 3 | F |
| 24 | F | 4 | F |
| 25 | F | 4 | F |
| 26 | T/F | 3 | F |
| 27 | T | 4 | T/F |
| 28 | T | 1 | F |
| 29 | T | 2 | F |
| **Average** | **4-T 4-F 2-T/F** | **3** | **9-F 1-T/F** |
| **Pct. True** | **40%** | | **0%** |
| **StdDev** | | **1.05** | |
| | | | |
| 30 | T/F | 3 | F |
| 31 | F | 3 | F |
| 32 | T | 4 | T |
| 33 | F | 4 | F |
| 35 | F | 5 | T |
| 36 | F | 1 | F |
| 37 | T | 3 | T |
| 38 | F | 3 | F |
| **Average** | **2-T 1-T/F 5-F** | **3.25** | **3-T 5-F** |
| **Pct. True** | **25%** | | **38%** |
| **StdDev** | | **1.17** | |

| Control # | Subjects' Comments (referenced by question # as applicable) |
|---|---|
| **10** | Light sound machine treatment caused all day headache. Adjusted volume/intensity. |
| **11** | 3) Relaxed after relaxation period (had been sitting at computer for 3 hrs prior to participation). 9) After exam was physically tired, but more focused. Helped later in the day with other projects |
| **12** | 3) Vision in right eye out of focus. This lasted only for first few minutes of evaluation period. 9) # hours after participation, developed a headache. |
| **13** | 3) More alert, possibly on edge. 8) Alert but did not want any more visual activity at that time. Eyes were tired, but not mental state. Past thinking, but leave my eyes alone. 9) After eyes rested, was fine remainder of the day. |
| **15** | Relaxation period was spent trying to "figure out" what L/S were for. Online portion spent looking for "subliminals" in flashing background. Shapes exam very difficult. |
| **17** | 3) Felt very relaxed and lethargic ("heavy" muscles). 6) Not necessarily fast thinking, but alert and frustrated. 7) Muscles no longer lethargic. |
| **18** | 5) Frustrated with not being able to distinguish shapes in the patterns. Some anxiety because I wanted to see the patterns at the same time without scrolling. 7)Eyes felt tired and strained |
| Summary | 2 headaches, 1 out of focus vision in one eye, 2 relaxed, 1 alert/on edge, |
| | |
| **20** | 7) Felt frustrated and a little more agitated after completing the online evaluation. Believe this made me physically more active (in a nervous way) and my heart rate increase. |
| **21** | No comments |
| **22** | No comments |
| **23** | 3) More at ease, lower heart rate. Different music would inspire a different reaction. |
| **24** | No comments |
| **25** | Relaxation period enhanced my performance on the evaluation, however it did not continue past the evaluation phase. |
| **26** | No comments |
| **27** | 7) Made me feel queasy, unable to focus. 9) Residual effects all that evening. Came out thinking that I never wanted to do it again. |
| **28** | 3) Relaxation period made me drowsy and tired...had a tough week on top of it. 7)Evaluation made me frustrated and tired, found the problems difficult |
| **29** | Tired before starting evaluation. Relaxation period did help me get relaxed and in a good frame of mind |
| **Summary** | **(1- queasy, 1 residual effects) 3) 3 relaxed 7) 2- frustrated/nervous, 1 - increased HR 9) 1 "residual effects"** |
| | |
| **30** | No comment |
| **31** | Felt relaxed (not necessarily tired) after the relaxation period. The difficulty of Part 1 was far greater than that of Part 2. |
| **32** | 3) Felt less tense after relaxation period. 7) Experienced slight headache afterwards. 9)Experienced slight headache afterwards |
| **33** | 2) My mind was relaxed, so I probably wasn't real alert, but I felt good. 3)helped me relax |
| **35** | 9) Approximately 30-60 minutes after the evaluation. I had a pretty painful headache. |
| **36** | 3) Made me tired. |
| **37** | I began to feel nervous soon after the evaluation began, and continued to feel queasy for 2-3 hours afterwards (much like motion sickness) Also had a slight headache for the rest of the day. |
| **38** | 3) Much more refreshed after the relaxation than I had been when I walked in. |
| **Summary** | **(3 headaches, 1 queasy) 3) 4 relaxed/refreshed, 1-tired 7,9)headaches** |

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